NEW

The SPACE RACE

THE COLD WAR'S COSMIC BATTLE FOR THE STARS

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Digital Edition

FUTURE

THIRD EDITION

SPUTNIK ★ APOLLO MISSIONS ★ CREATING NASA ★ MAN ON THE MOON

WELCOME TO The SPACE RACE

When Neil Armstrong took those first, fateful steps on the surface of the Moon, he uttered the now-timeless phrase "that's one small step for man, one giant leap for mankind". His words may have sounded effortless, but the long-awaited mission to get to the moon was nothing short of astronomical.

Behind the quiet solitude of the moon lay the efforts of the hundreds of thousands of people, who had all contributed in some way to the mission's success. But there was also another important element - the fierce rivalry between the USA and the USSR that was raging back on Earth.

What began as a dark Nazi art of building long-range missiles, designed to rain down over Europe, had turned into a technological race between the world's greatest superpowers by the end of the 1950s. The Soviet Union had surprised the world and kicked off the race towards Space by launching Sputnik, the bare bones satellite that became the first man-made object to orbit Earth. The USA had to respond - and in a big way.

Over the next decade, the two countries battled it out to gain important victories over one another, culminating in NASA's Apollo 11 mission in 1969. But the Space Race didn't end there - the 1970s ushered in an era of new achievements, and even cooperation between the former rivals. Flick through the pages of this book to find out more about the golden era of Space exploration, get to know the astronauts and their teams, revel in the joy of a good mission and see what went wrong in tragic disasters. Finally, look into the future to see where mankind may put their footprint next.

FUTURE

The SPACE RACE

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Alice Barnes-Brown**
Designer **Madelene King**
Compiled by **Sarah Bankes**
Senior Art Editor **Andy Downes**
Head of Art & Design **Greg Whitaker**
Editorial Director **Jon White**

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Commercial Director **Clare Dove**

International
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com
www.futurecontenthub.com

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Matthew Eglinton**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Managers **Keely Miller, Nola Cokely,**
Vivienne Calvert, Fran Twentyman

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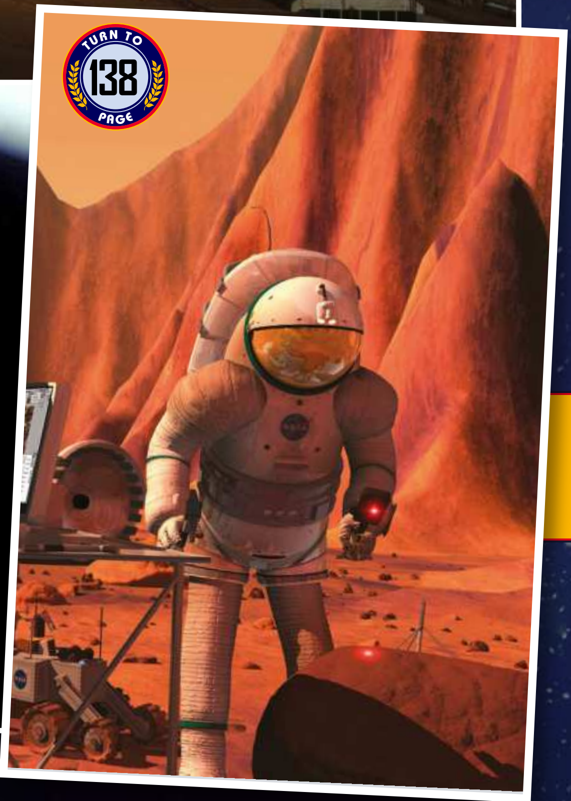

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TIMELINE

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V1 AND V2 ROCKETS INVENTED

1944-1945

Prophesied as the weapon that would turn the tide of WWII in Germany's favour, the Vergeltungswaffens (retribution weapons) may not have won the war for the Nazis, but they did give rise to the world's first rocket – the V2. Carrying the same 1-ton explosives payload as its predecessor, the V2 was a far more formidable weapon due to its speed – an incredible 3,580 miles per hour. Fueled by a liquid-propellant rocket engine, a V2 crossed the Kármán Line (the boundary between Earth's atmosphere and space) in June 1944.

US ARMY CHECKPOINT
YOU ARE LEAVING THE AMERICAN SECTOR
ВЫ ВЫЕЗЖАЕТЕ ИЗ АМЕРИКАНСКОГО СЕКТОРА
VOUS SORTEZ DU SECTEUR AMERICAIN

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SPUTNIK LAUNCHED

4 OCTOBER 1957

Propelled into orbit from a Soviet base in Baikonur, Kazakhstan, Sputnik 1's launch marked the Soviets' triumph in the efforts to enter space first and, more importantly, the first time that an artificial satellite would ever orbit Earth. Weighing just over 83 kilograms and comprising of two metal spheres and four radio antennae, Sputnik orbited Earth for three weeks before its batteries died, travelling at approximately 18,000 miles hour. This brief flight provided incredibly valuable information on the make up of Earth's upper atmosphere.

TURN TO 20 PAGE

COLD WAR BEGINS

1947

The Cold War between the US and the Soviet Union brought to the surface long-suppressed tensions that had begun to fester even before the two had worked together to defeat Nazi Germany. While the US vowed to 'contain' any Soviet efforts to expand, the Soviets resented America's interventionist nature and refusal to recognise them as an equal power on the global stage. In a bid to outdo each other both nations turned their gaze to space, starting a race for the stars that only one could hope to win.

TURN TO 26 PAGE

NASA FOUNDED

29 JULY 1958

Inspired to act by successful Soviet launches, America moved quickly to establish the National Aeronautics and Space Administration (NASA). There were several arguments as to whether the new agency should be a military or civilian endeavor, but once the latter had triumphed and both congressional and presidential committees had explored the concept in detail, all that remained was for Congress to pass the necessary legislation. It did so on 27 July, and just two days later NASA was signed into law by President Eisenhower. America had finally entered the space race.

FIRST MAN IN SPACE

12 APRIL 1961

Born on 9 March 1934 in Smolensk, Yuri Alekseyevich Gagarin turned his back on a life of labour to join the Soviet Air Cadets and then the Soviet Air Force. By 1959 he had risen to the rank of Senior Lieutenant while based in Murmansk. An excellent pilot, he was selected along with 19 others to participate in the Soviet space programme. He duly passed a battery of tests and was rewarded with selection for the Soviets' first attempt to send a man into space. Strapped into Vostok 1, Gagarin flew into the history books in April 1961, orbiting the globe for 108 minutes before landing safely back in Kazakhstan.

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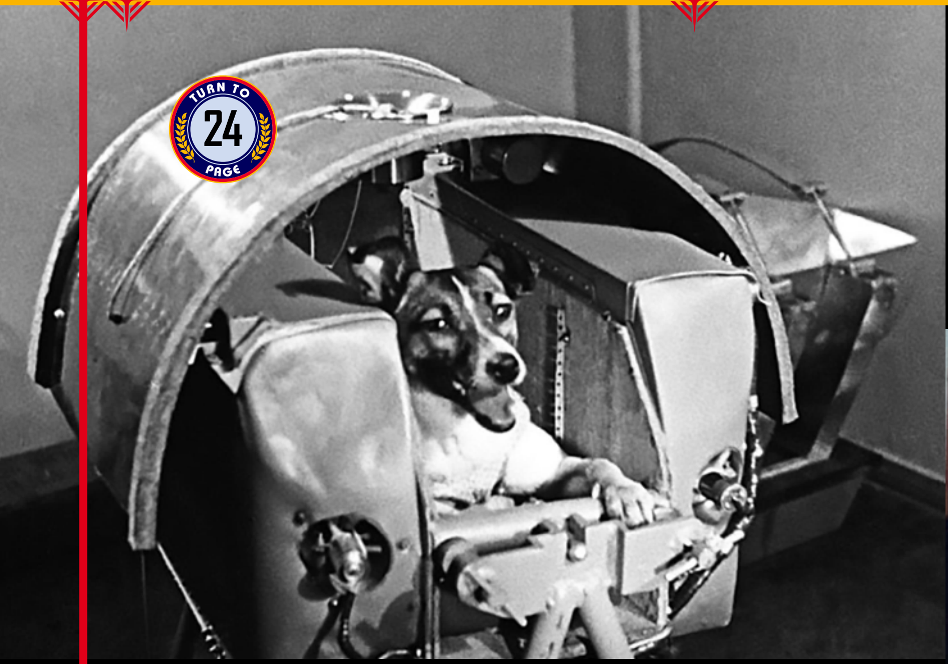

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LAIKA – SPACE CANINE

7 NOVEMBER 1957

Selected from among a host of canine candidates, three-year-old Laika, a stray from the streets of Moscow, was sent into orbit abroad Sputnik 2 on 7 November 1957 with seven days' worth of oxygen and one meal, becoming the first animal to enter space. Sadly for Laika, her journey was to be briefer than expected, with temperatures of 90-degrees Celsius inside her capsule proving too much. However, her sacrifice was not in vain because her ability to survive for any length of time in space proved to scientists that the final frontier was indeed one that mammals could function in.

FIRST AMERICAN IN SPACE

5 MAY 1961

No longer able to claim the title of the first man in space, Alan Bartlett Shepard, a navy veteran of WWII, was able to boast of being the first American to enter orbit when he blasted off aboard the Mercury-Redstone 3 rocket in May 1961. Watched by millions live on TV, Shepard piloted the Freedom 7 capsule for a 15-minute flight, during which he reached an altitude of 116.5 miles.

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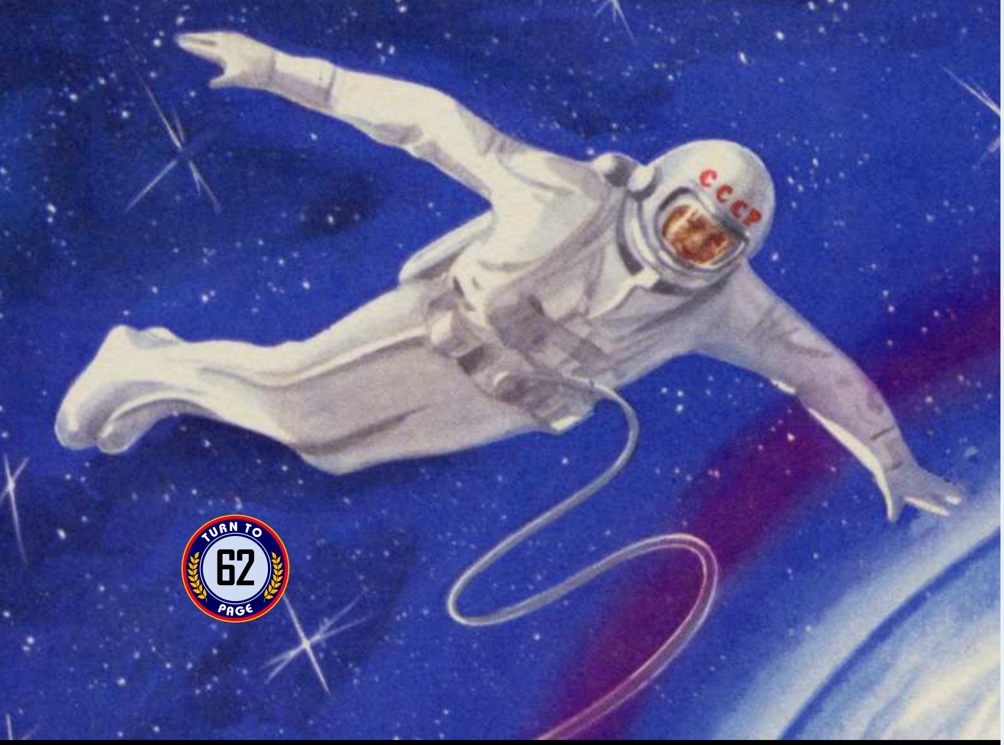

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FIRST SPACEWALK

18 MARCH 1965

In yet another Soviet step forward, 30-year-old Alexei Leonov completed the first ever spacewalk during his mission aboard Voshkod 2 in early 1965. Working on the spacecraft with his fellow cosmonaut Pavel Belyayev, Leonov floated out of a hatch and into the vast emptiness of space, an experience he later described as making him feel like "a seagull soaring above the Earth". Leonov spent ten minutes outside the spacecraft before re-entering, a process fraught with danger as his suit had become warped, forcing him to release oxygen from his suit in order to clamber back inside.

PROJECT GEMINI

1965

NASA's second human spaceflight programme began in 1965 and feature a number of crews flying on various missions aboard two-man Gemini spacecraft. Larger than its Mercury predecessors, the Gemini type spacecraft was equipped to alter its own orbital path. This level of flexibility helped Geminis 3 to 12 achieve many breakthroughs for America's fledgling space agency, including the first US spacewalk and Gemini 8 connecting to an unmanned spacecraft in orbit. All of this paved the way for the Apollo missions that followed.

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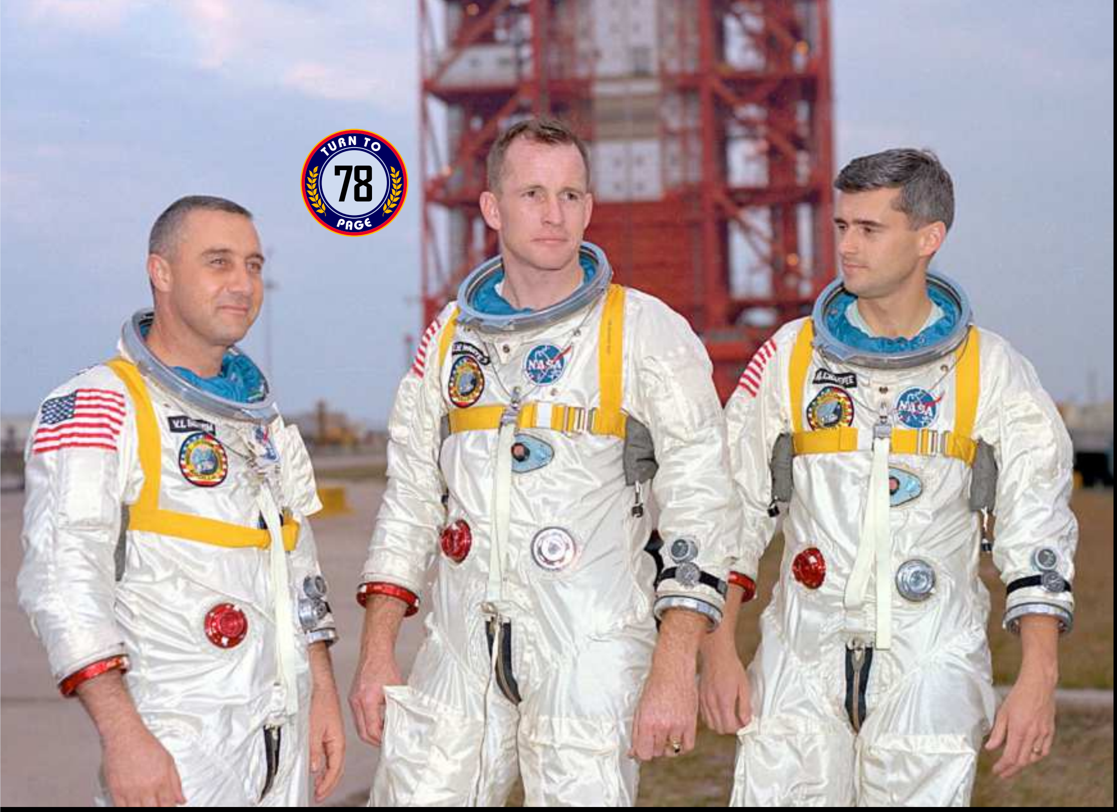
FIRST WOMAN IN SPACE

16 JUNE 1963

With a keen interest in parachuting and an education from the Zhukovsky Air Force Engineering Academy in Moscow, 26-year-old Valentina Tereshkova was an ideal candidate to be the first woman sent into space. Following a period of intensive training she was strapped into Vostok 6 on the morning of 16 June 1963 (having followed the rather bizarre ritual of urinating on a tyre of the bus that transported her to the rocket, first established by Yuri Gagarin) and sent into space for three days.



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APOLLO 1 DISASTER

27 JANUARY 1967

In early 1967 NASA's seemingly unstoppable march was brought to a devastating halt when tragedy struck at Cape Kennedy's Launch Complex in Florida. On this fateful day Roger Chaffee, 31, Virgil 'Gus' Grissom, 43, and Ed White, 36, perished when a fire erupted in their capsule during a test flight. A Congressional investigation found that the doomed astronauts had been suffocated by toxic fumes and had also suffered burns.

TURN TO 82 PAGE

APOLLO 7

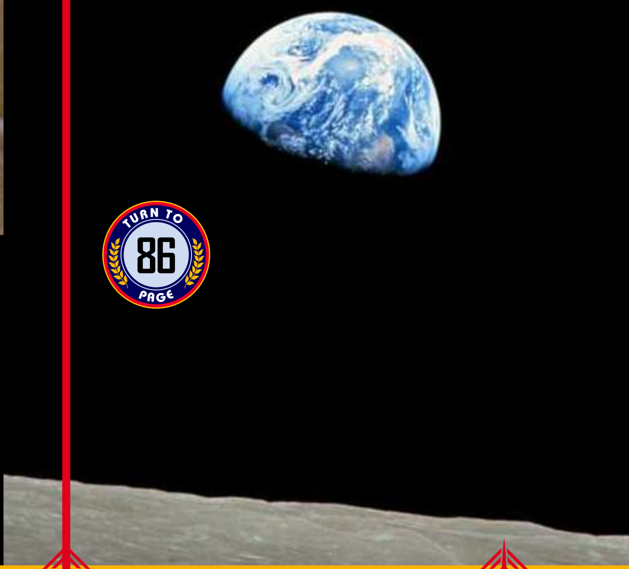
11 OCTOBER 1968

The first crewed Apollo mission would become notorious for the fractured relationship between the three-man crew aboard the Saturn rocket and ground control. Piloted by Walter Schirra, Donn Eisele and R Walter Cunningham, the mission initially enjoyed success as the crew conducted equipment experiments. However, poor food, inadequate waste disposal and the onset of colds led to a marked deterioration, with the crew refusing to engage in a live TV stream or wear their helmets upon re-entering Earth's atmosphere due to sinus problems.

APOLLO 8

21 DECEMBER 1968

In another key step forward for NASA, the Apollo 8 mission was the first to leave low Earth orbit to orbit the Moon, thereby proving that humans could safely approach our natural satellite and return home. It was during this flight that the crew took the now famous 'Earthrise' photo.



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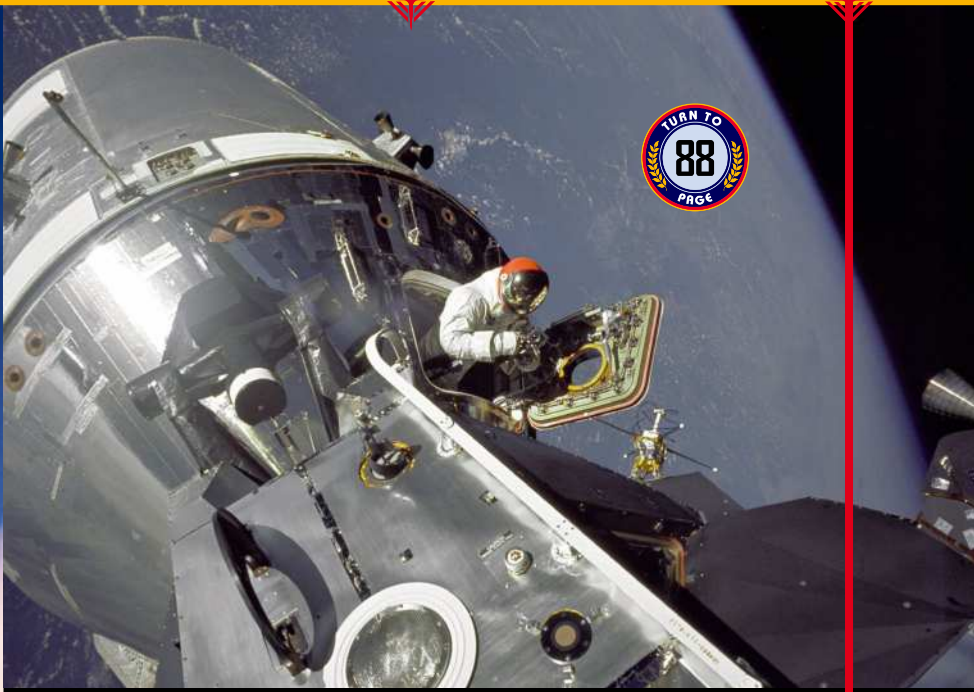

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APOLLO 9

3 MARCH 1969

This mission saw the first use of the command and service module in conjunction with an Apollo lunar module, as well as a number of manoeuvres conducted in preparation for the 1969 Moon landings. Yet by far the most significant moment came on the fourth day of the flight when crew members Dave Scott and Rusty Schweickart engaged in the first ever Apollo spacewalk, something Scott captured on camera.

APOLLO 10

TURN TO PAGE 94

18 MAY 1969

Viewed as a dress rehearsal for the main event just two months later, Apollo 10 sent the first live colour transmissions from space and set a record for the highest speed reached by a crewed vehicle when it hit 24,790.8 miles per hour during its return from the Moon's orbit. However, it very nearly set a different – and completely unwanted – record while flying to within just 9.7 miles of the lunar surface when the crew overloaded the spacecraft with instructions, an error that sent it into a spiral that almost saw them smash into the Moon.

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APOLLO 13

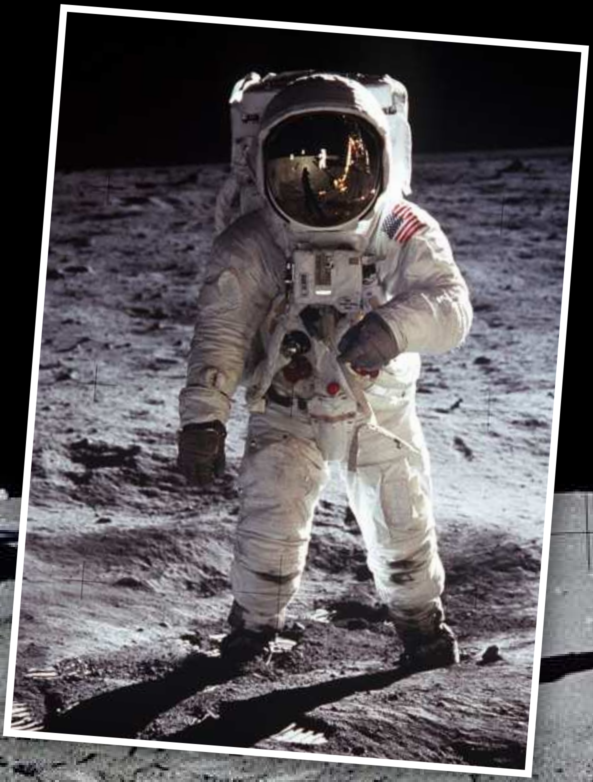
11 APRIL 1970

Keen to follow up its earlier triumphs, NASA launched its Apollo 13 spacecraft (comprised of two parts connected by a tunnel) with the intent of placing men on the Moon for a third time. Instead they very nearly witnessed the death of their entire crew when an oxygen tank exploded in Odyssey, leading to a dramatic loss of power, a moment that gave rise to the infamous remark, "Houston, we've had a problem." Luckily the crew could rely on the second segment of the spacecraft, Aquarius, to get them home.

MEN ON THE MOON

20 JULY 1969

Arguably NASA's crowning moment to date, the Moon landing of July 1969 was a seminal moment in the history of humankind. While Michael Collins remained in the Apollo 11 command module, Columbia, Neil Armstrong and Buzz Aldrin made for the lunar surface in the Eagle lunar module, Armstrong deftly avoiding a boulder-strewn patch to touch down at 20:17 UTC. He immediately radioed home: "Houston, Tranquility Base here. The Eagle has landed."



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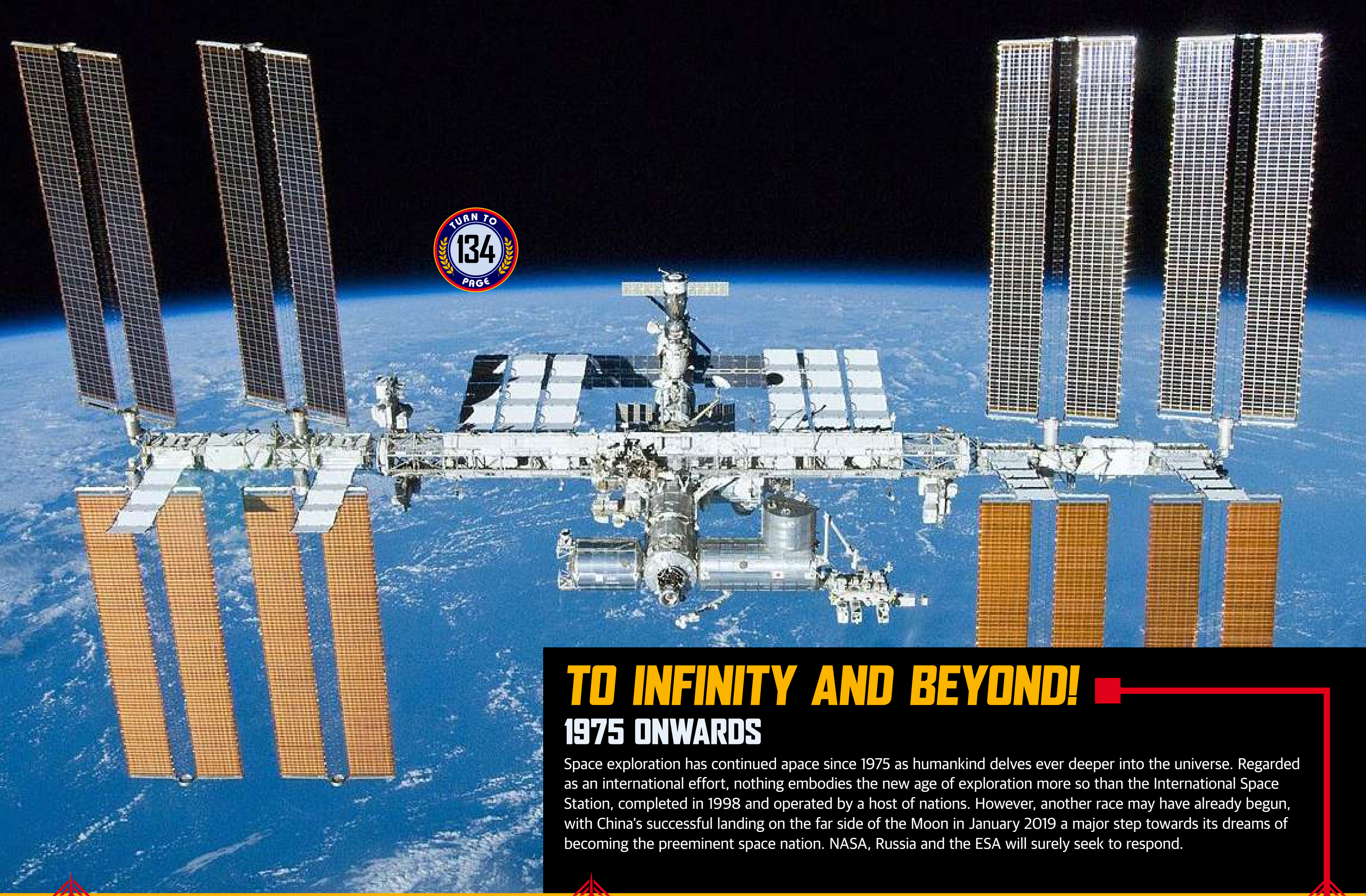

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TO INFINITY AND BEYOND!

1975 ONWARDS

Space exploration has continued apace since 1975 as humankind delves ever deeper into the universe. Regarded as an international effort, nothing embodies the new age of exploration more so than the International Space Station, completed in 1998 and operated by a host of nations. However, another race may have already begun, with China's successful landing on the far side of the Moon in January 2019 a major step towards its dreams of becoming the preeminent space nation. NASA, Russia and the ESA will surely seek to respond.

SOYUZ 11 DISASTER

30 JUNE 1971

Having spent 23 days in space, the crew of the Soviet spacecraft Soyuz II prepared to re-enter the Earth's atmosphere. As their descent module detached, they were totally unaware that a ventilation valve had become dislodged. Their flight back to Earth seemed to proceed as expected, but when ground crew opened the hatch to let them out, they found the three crew members dead in their seats. The broken valve had led to a catastrophic depressurisation that resulted in the asphyxiation of the crew, who sadly became the first people to die in space.

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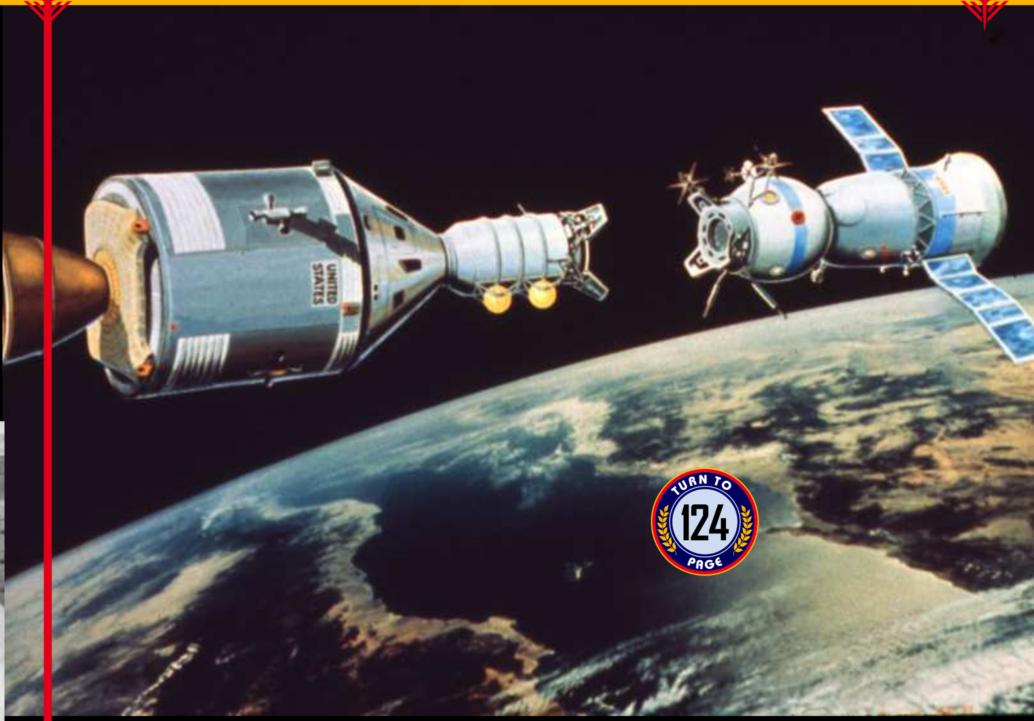

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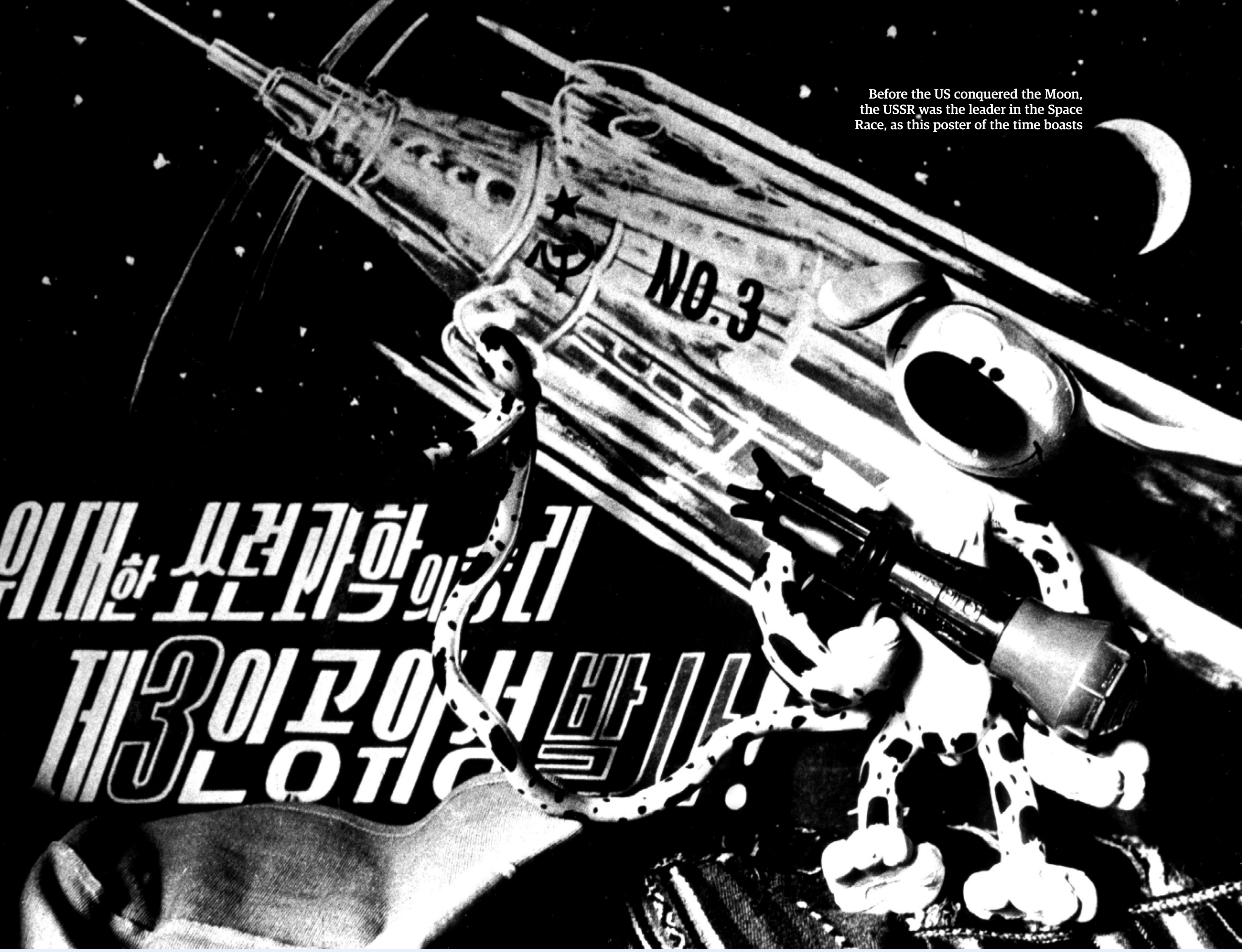
APOLLO-SOYUZ TEST PROJECT

JULY 1975

In a huge breakthrough in relations between the US and the Soviet Union, the Apollo-Soyuz Test Project was the first international space mission and involved three American and two Soviet astronauts working together to conduct five joint experiments. The Apollo Command/Service Module 111 and Soyuz 19 capsule were able to connect in orbit thanks to a docking module built by NASA.

© Getty Images, Alamy, NASA



Before the US conquered the Moon, the USSR was the leader in the Space Race, as this poster of the time boasts

The COLD WAR'S FINAL FRONTIER

After World War II, the US and USSR were combatants in a new kind of war – one that set its sights higher than earthly gains

★ **Written by April Madden** ★

The end of World War II was supposed to have brought about peace. Instead, it gave rise to a new kind of conflict, one whose stakes were even higher than the conquest of territory on Earth. German rockets may no longer have been falling on the cities of Europe, but in out-of-the-way factories and aerodromes across the United States and the Soviet Union, the technology that had propelled them was rising again.

Shortly before the end of World War II, the Yalta Conference was held by the leaders of Britain, the United States and the Union of Soviet Socialist Republics (USSR). Here, they agreed several key points regarding the fate of Germany in the event of an Allied victory. Germany itself was to be disassembled, and its territories were to be shared out between neighbours and interested parties. More importantly, so were its assets, in reparations. But tangible goods weren't the only thing that could be used to pay off the German war debt - the Allied leaders Churchill, Stalin and Roosevelt agreed that forced labour by captive German citizens was also an acceptable method of payment. So when Berlin fell in May 1945, that's exactly what happened.

The US and the USSR both had reasons to be very interested in the V-2 rockets that had nearly brought Britain to its knees. Tensions between the two countries had been rising since the Russian Revolution of 1918; the only thing that had brought the Soviets to the table with the Americans was the USSR's betrayal by Germany in June 1941. The Soviets were unwilling to trust anyone who professed to be an ally; the staunchly capitalist US was alarmed that the USSR's socialist blandishments would rouse its own long-suffering proletariat, who had only just emerged from the deprivations of the Great Depression recently, largely thanks to the extra labour demands created by the war effort. The USSR had an expansionist agenda fuelled by its dream of a new, communist world; the US was perfectly happy with the status quo, which allowed it to profiteer freely throughout the international community.

Neither fully understood or trusted the other; both believed that the other's way of life was opposite and inimical to everything that it held dear. Both thought that the prospect of an ideological and physical war between them was an inevitability, and they wanted to be prepared. The USSR in particular, as shocked and awed as the rest of the world by the game-changing nuclear weapons that the US had unleashed on Japan in August 1945, wanted the confidence to know that it could go toe to toe with its mighty enemy. And the way to do that was with the incredible missile technology that could be gleaned from the wreckage of Germany.

Nuclear warfare had appalled the world. The unimaginable devastation and loss of life unleashed at Hiroshima and Nagasaki had made even their destroyers step back in horror and question what they had done. Any public arms race between the US and the USSR, therefore, was not going to be enacted through the medium of nuclear destruction -

> "Both believed that the other's way of life was opposite and inimical to everything that it held dear"

Both the USSR and US developed and stockpiled nuclear weapons. The Space Race was a more propaganda-friendly facet of their arms race

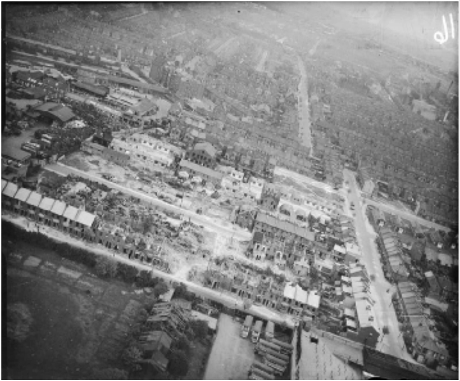
THE V-2 ROCKET

THE WORLD'S FIRST GUIDED BALLISTIC MISSILE GAVE RISE TO THE SPACE RACE

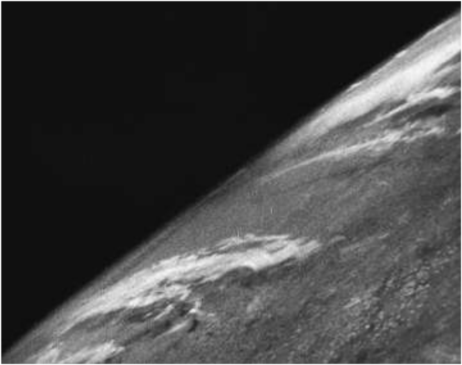
During World War II, Germany had embarked on an extensive bombing campaign against Britain, known as the Blitz. In response, Britain's nascent Royal Air Force rose to the challenge; fighters took on German aircraft in the skies and bombers levelled German cities. Now the Germans needed a more reliable way of delivering ordnance to targets without risking expensive aeroplanes and their crews. The Vergeltungswaffe-2, or 'retribution weapon', was born.

The brainchild of rocket scientist Wernher von Braun, the V-2 was responsible for the deaths of over 9,000 European civilians and personnel, and a further 12,000 slave labourers and concentration camp prisoners. A V-2 was also the first manmade object in space, crossing the Kármán line in June 1944. The V-2 required its operators to have some knowledge of its target; it only had a limited amount of time during takeoff in which its navigational systems could be set to the right angles to ensure it came down in the right place. Nonetheless it was a game changer.

At the end of World War II, V-2's designer and many of his staff defected to the US and ended up working at the American Redstone Arsenal, developing space technologies. Meanwhile the Soviets claimed the factories themselves, disassembling them and rebuilding them in Russia, where they continued to produce V-2 missiles. The liquid fuel used in the V-2 missiles was a technical innovation that allowed the first space-going rockets to be built and is still used in spacecraft to this day.



The damage caused by a single exploding German V-2 rocket in East Ham, London, in 1945



The first photo ever taken from space was captured by a camera aboard an American V-2 rocket in 1946

EMERGING FROM VON BRAUN'S SHADOW

HELMUT GRÖTTRUP WAS A KEY MEMBER OF THE GERMAN ROCKET ENGINEERING TEAM

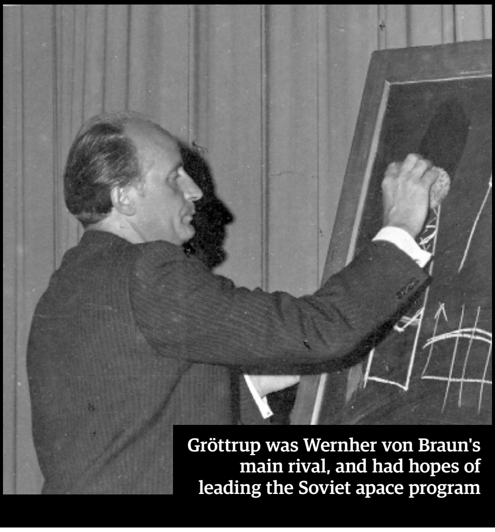
On 22 October 1946, between midnight and 3am, German scientist Helmut Gröttrup, his wife and their two children were suddenly awoken and forced, at gunpoint, onto a train by Soviet troops. Along with over 2,000 others, they were taken to the Soviet Union, where Gröttrup was put to work redesigning and rebuilding the V-2 rockets he'd worked on in Germany.

Gröttrup had been an underling of Wernher von Braun's during World War II and he was keen to demonstrate that he was just as much of an innovator as the charismatic leader of the V-2 programme. He ended up under the supervision of Sergei Korolev, the USSR's lead rocket engineer and spacecraft designer.

Once Gröttrup found himself in Soviet territory, he and Korolev had something in common: both had to work, designing rockets, as prisoners of the Soviet government. Both were expedient enough to make the best of a terrible situation, and both were eventually freed.

It was on Korolev's watch that the USSR achieved many of its early victories in the Space Race. He designed the R-7 rocket booster that put Sputnik 1, Sputnik 2, the dog Laika and cosmonaut Yuri Gagarin into space. Gröttrup was tasked with coming up with alternative designs to ensure that the Soviet space effort was as fast and efficient as possible, and that its design teams weren't missing anything. It was a tactic that saw the USSR shoot ahead in the early Space Race.

Gröttrup returned to East Germany in 1953, but he didn't stop working. He is now most famous for the early incarnations of the smart card.



Gröttrup was Wernher von Braun's main rival, and had hopes of leading the Soviet apace program

Gröttrup was also responsible for early groundbreaking work on the smart card, which led directly to mobile phone SIMs, chip-and-PIN technology, and contactless payments

nobody would be left alive to cheer for the victor. The concept of mutually assured destruction was what kept the Cold War cold: the idea that the vast arsenals of almighty weapons could obliterate life on Earth was a powerful disincentive to open conflict. But what they could publicly brag about to their citizens and to each other was the development of the world-changing technology required to deliver these vast nuclear warheads to their destinations without risking the uncertainties of using bomber planes, the precision-targeted missiles that could deliver destruction from a continent away with the turn of a key. And that was precisely the technology Germany had been working on.

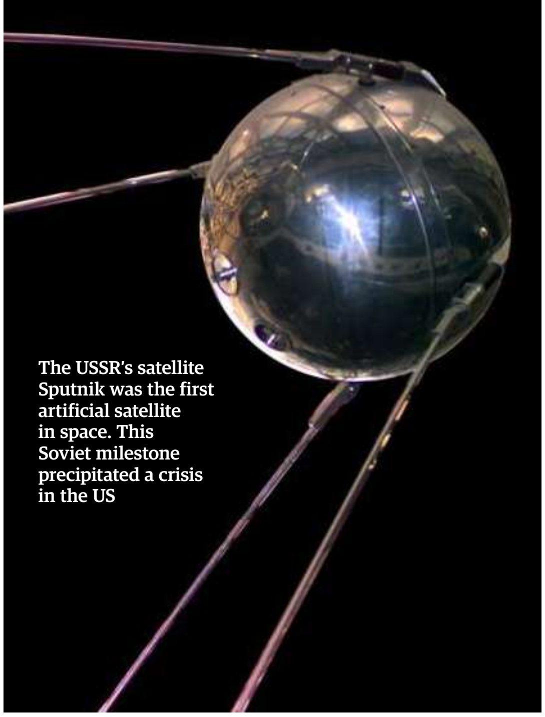
In the last days of World War II, the US and the USSR both sought out and captured thousands of German science specialists. They were the world's largest developed nations at that point, as the last remnants of Europe's colonial empires finally crumbled. Both were aware that their size, resources and grasp of new technology could make one of them the most powerful country in this new, postwar world. Germany, meanwhile, had been at the forefront of rocket technology; it had been capable of sub-orbital flight as early as the 1930s. Many of Germany's most important laboratories and factories were in the Soviet Occupied Zone of the fallen nation; the Soviets removed thousands of scientists and their families to the USSR in a single night on 22 October 1946 in Operation Osoaviakhim.

But the US was one step ahead – immediately after the end of the war it had issued evacuation notices to many scientists in the Soviet Occupied Zone and removed them to its own territories. Germany's leading aerospace engineer and rocket scientist, Wernher von Braun, had willingly surrendered to

The US and USSR danced on the brink of nuclear war, as rising Cold War tensions resulted in incidents like the Cuban Missile Crisis

Soviet cosmonaut Yuri Gagarin had the distinction of being the first human being to ever travel into space

US scientists William Hayward Pickering, James Van Allen and Wernher von Braun display a model of the Explorer 1 satellite, the second successful American launch


The USSR's satellite Sputnik was the first artificial satellite in space. This Soviet milestone precipitated a crisis in the US

Wernher von Braun, Germany's leading rocket scientist and aerospace engineer, defected to US forces to avoid capture by the Soviets

> "That was precisely the technology Germany had been working on"

them. The US offered its German scientists and their families new, although secretive, lives, freedom from prosecution at the Nuremberg Trials, and the opportunity to continue their research under the auspices of the US military through Operation Paperclip. The USSR's terms were somewhat more forceful. Nonetheless, both nations cited the Yalta Conference agreement regarding forced labour - now using the high-minded terminology of 'intellectual reparations' - to justify their actions, and both blamed the other for the apparent need to do so.

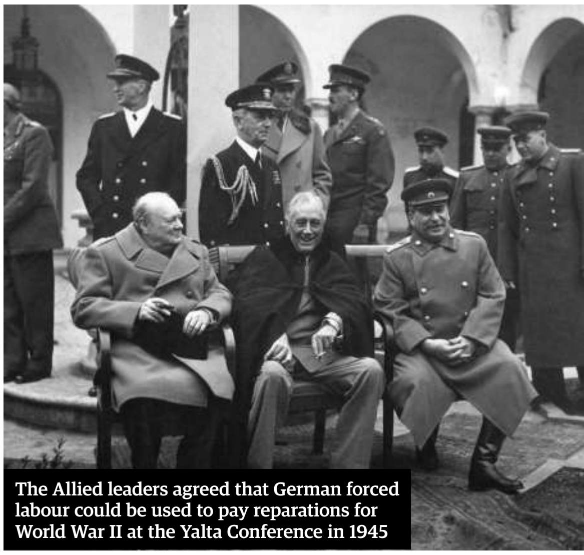
By the 1950s, both nations were broadly confident that their missile technology was capable of wiping out the other, and they began to turn their attention to other with more public demonstrations of their power. In 1952, a worldwide scientific event called the International Geophysical Year was announced. Planned for 1957-58, its aim was to bring nations together to celebrate Earth sciences, including the nascent space technologies the US and USSR were both working on. Both immediately saw the propaganda value of the event and set to work.

On 29 July 1955, the US made the surprise announcement that it planned to launch the world's first artificial satellite in 1957 or 1958. The USSR countered four days later with the reply that it too planned to launch a satellite in the very near future. In part, then, what became the Space Race began as performative posturing, propaganda as theatre with its stage as the stars, although what happened next is almost farcical.

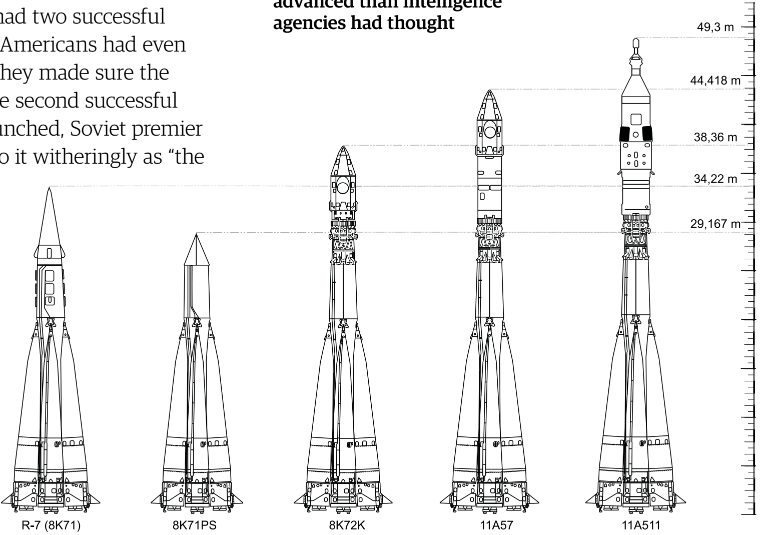
The US dithered over the use of its new Jupiter-C rocket technology as a launch vehicle, feeling that the massive von Braun-designed missiles could be misconstrued by other nations as active warheads. The USSR assumed the US would be using a Jupiter-C; when intelligence of a test launch reached them they interpreted it as a significant milestone in the US programme and sped up their own. Knowing that the US planned to present a paper entitled *Satellite Over the Earth* during the International Geophysical Year, the USSR assumed a launch date for the US satellite and set out to beat it. They did: Sputnik 1 became the world's first artificial satellite on Friday 4 October 1957.

The USSR couldn't have hoped for a better result: the US was plunged into crisis. The American military worried that Soviet technology was far ahead of their own. Handwringing editorials in American newspapers didn't help; the nation, they claimed, was busy amusing itself designing unnecessary new cars and gadgets with its so-called technical prowess while the Soviets were out conquering space. American intelligence services suddenly realised that they'd been so focused on nuclear technologies that they'd ignored other Soviet areas of research, as well as the fact that the USSR had been training three times as many scientists as the US for the past decade. American scientists realised that they couldn't do the maths that explained the amount of force required to launch Sputnik 1 - roughly three times as heavy as the putative US satellite design - or rather, that they could, but the equation produced a theoretical rocket much more powerful than the best of the current US designs.

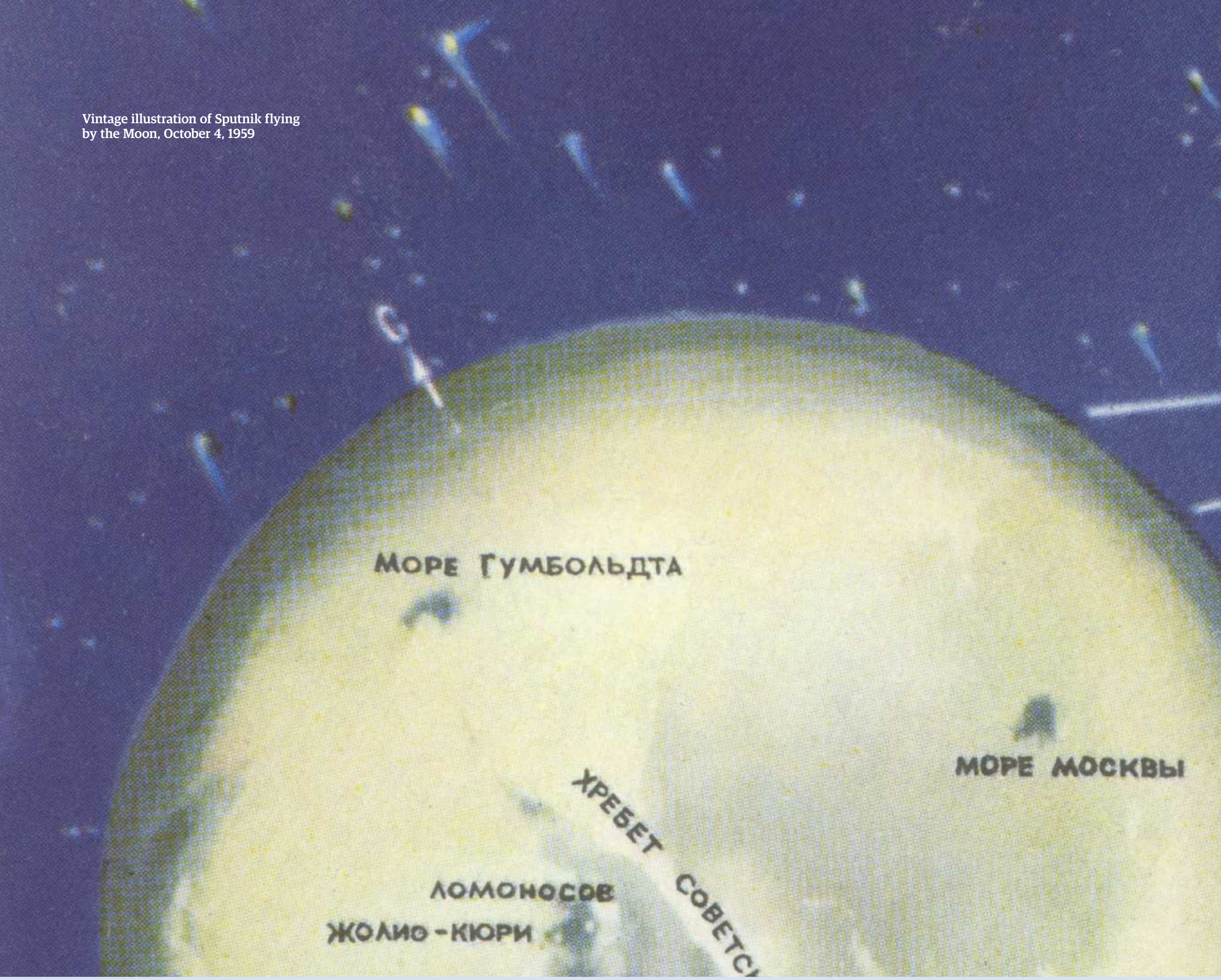
Rushed satellite launch attempts by the US Navy were plagued with failures until finally the American design for the International Geophysical Year was ready - and then the USSR launched Sputnik 2. The Soviets now had two successful satellites in space before the Americans had even got one off the ground, and they made sure the Americans knew it. When the second successful US device was eventually launched, Soviet premier Nikita Khrushchev referred to it witheringly as "the grapefruit satellite". And the USSR hadn't finished taunting the US, either. A volley of unmanned lunar probes followed. Here the US had a few successes, but nothing as dramatic as that first Soviet victory. And then, on 12 April 1961, Russian cosmonaut Yuri Gagarin became the first man in space. The US had quietly known that the USSR was likely to be the one to achieve that most important milestone, but it was a blow to their national self-esteem nonetheless. After this, the USSR couldn't be allowed to beat them again. The Space Race had just got personal.


The Allied leaders agreed that German forced labour could be used to pay reparations for World War II at the Yalta Conference in 1945

Designs for Soviet rockets. When Sputnik I successfully launched, the US realised that the USSR's rocket technology was further advanced than intelligence agencies had thought



© NASA, Creative Commons; Hywel Clatworthy


МОРЕ ГУМБОЛЬДТА
МОРЕ МОСКВЫ
ХРЕБЕТ СОВЕТС
ЛОМОНОСОВ
ЖОЛИО-КЮРИ

Vintage illustration of Sputnik flying by the Moon, October 4, 1959

20 SPUTNIK
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41 ANATOMY OF… A COSMONAUT

1950s

EXPLORING

SPACE ★ RACE

SENDING SPUTNIK to SPACE

Designed in a race against the Americans, the Soviet Union not only crossed the finish line, but with the launch of a simple satellite began an era of space exploration

Written by Scott Dutfield

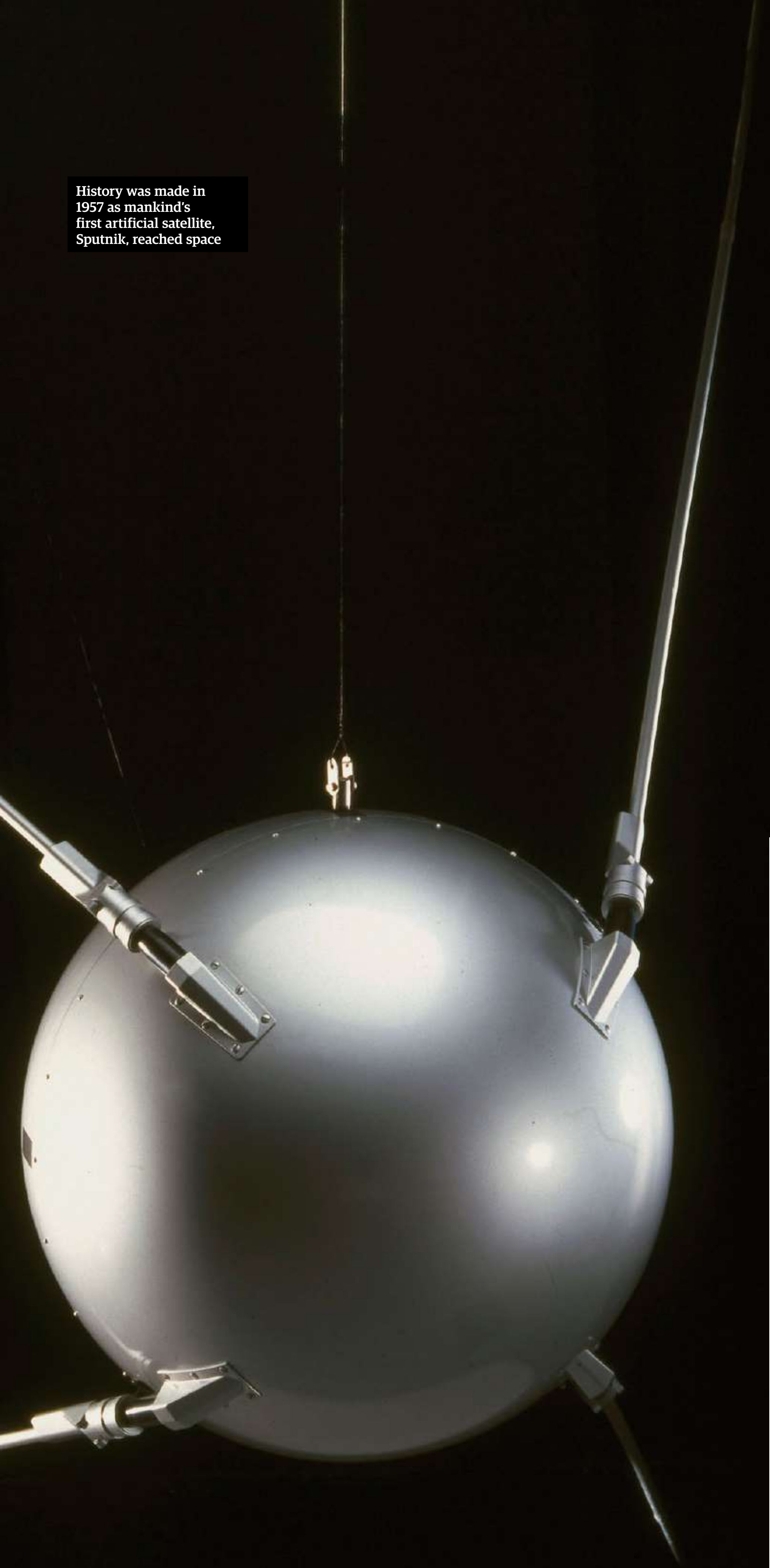
It was the satellite that fired the starting gun for the Space Race between two world powers. Designed to simply observe the Earth's atmosphere, Sputnik began a wave of technological achievements and became the Soviet Union's national treasure.

Following the end of the Second World War, both the United States and the Soviet Union had entered into the Cold War, beginning in 1947. A political and economic battle placed the nations at loggerheads. Both focused on the development of advanced military weaponry, including the creation of intercontinental ballistic missile (ICBM) technologies. Taking inspiration from the Germans' explosive endeavour, the V-2 rocket, the possibilities for nuclear warhead missiles became a growing concern and goal for both nations. However, in the early 1950s, sights were set on the heavens due to the role rockery could play in entering a new field of exploration - space.

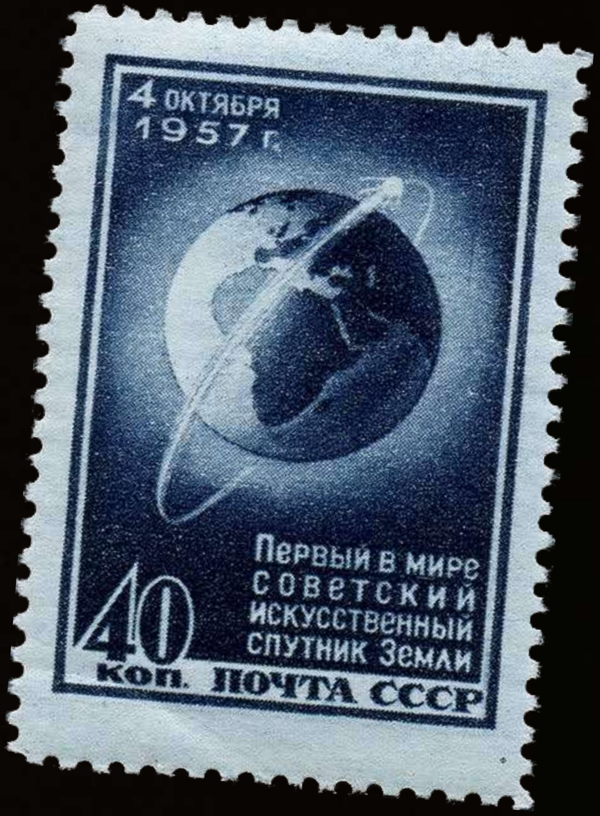
After a period of global diversity during the war, in 1952 National Academy of Science member Lloyd Berker proposed to the International Council of Scientific Unions (ICSU) a series of global geophysical activities. The project aimed to conduct a series of collaborative studies to further understand the Earth and its environment over a fixed period of time. Running from July 1957 to December 1958, this window of scientific exploration was known as the International Geophysical Year (IGY). From glaciation to gravity, over 70 countries took part in projects that would lead to the understanding of plate tectonics and polar regions and the discovery of the Van Allen radiation belt.

In July 1955, United States President Dwight Eisenhower announced the country's aim to launch an artificial satellite as part of the IGY, stating that: "The most important result of the International Geophysical Year is the demonstration of the ability of peoples of all nations to work together harmoniously for the common good. I hope this can become a common practice in other fields of human endeavour." Seeing this announcement as a challenge, the Soviet Union followed suit, announcing its plans to achieve the same feat a month later. The rebuttal, however, was not based on an existing project already in motion, rather a consequence of the Cold War.

The Second World War had played host to the latest rockery weapons. However, none of these were capable of launching a satellite. In order to achieve this astronomical feat of engineering, a satellite would first need a way to surpass the



History was made in 1957 as mankind's first artificial satellite, Sputnik, reached space



The former USSR released a commemorative stamp to celebrate Sputnik's success

A CASE OF MISTAKEN IDENTITY

FLYING HIGH IN THE SKY, MANY THOUGHT THEIR GAZE HAD CAUGHT A GLIMPSE OF A PASSING SATELLITE. HOWEVER, NOT ALL WAS AS IT SEEMED

Met with the announcement of the first satellite launched into space, many people in both the Soviet Union and the United States rushed outside to see Sputnik for themselves. Due to Sputnik's aluminium appearance, the elliptical satellite often found itself catching the Sun's rays, illuminating its position in the sky. In fact, Sputnik was so reflective it could be seen from Earth's surface through a pair of binoculars – and if bright enough even the naked eye. Accompanied with its onboard radio beacon, Sputnik's shiny surface could also be used to locate its position around the globe during orbit.

Curiosity and concern over the satellite's existence formed a following of public observers, each trying to catch a glimpse of the revolutionary tech. On one fateful day in late 1957 officials received a rush of sightings claiming to see Sputnik clearly in the sky. However, their mass excitement is believed to have been the result of misidentification. In fact, what was thought to be Sputnik was indeed the rocket that had sent the satellite to space, the R-7. Sputnik wasn't alone in reaching orbit, because the rocket's 26-metre-long core stage went with it. It was also covered in reflective panels, placed for visual tracking of the rockets return. The rocket fell back to Earth in December 1957, aligning with the reported sighting.

Researchers used Sputnik's beeps and calculated trajectory to track its movements around the Earth

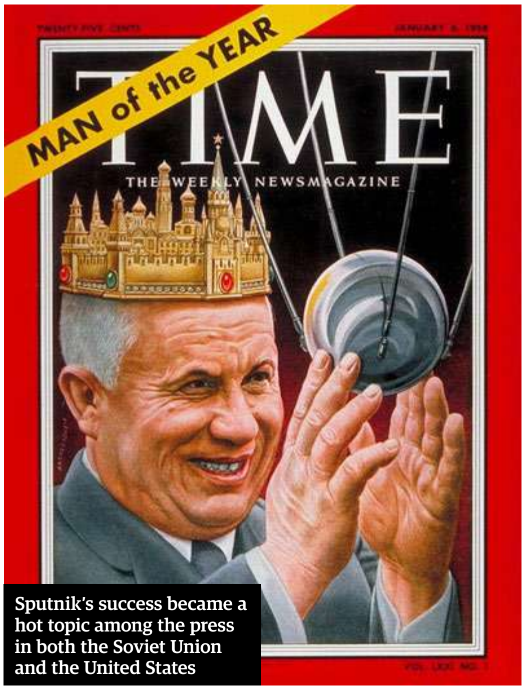
Sputnik's rise to fame resulted in the creation of toys to show the next generation Sputnik's triumphal orbit of the Earth

Earth's gravitational pull. Recognised as a leading expert in aeronautical engineering, Sergei Korolev, chief designer in the field, was a natural fit for undertaking the task of creating the Soviet's first ICBM. Heading the OKB-1, an aeronautical design bureau, Korolev and a team of the country's finest engineers - including engineer and aeronautical designer Mikhail Tikhonravov - began work on achieving the seemingly unachievable. Taking inspiration from the German V-2, Korolev developed the R-7 rocket, a 267-ton liquid-fuelled missile capable of around 396.9 tons of thrust. Stemming from the fruits of several versions, the R-7 promised to be the first rocket to see space. Now with a method of delivery, attention turned to the satellite itself.

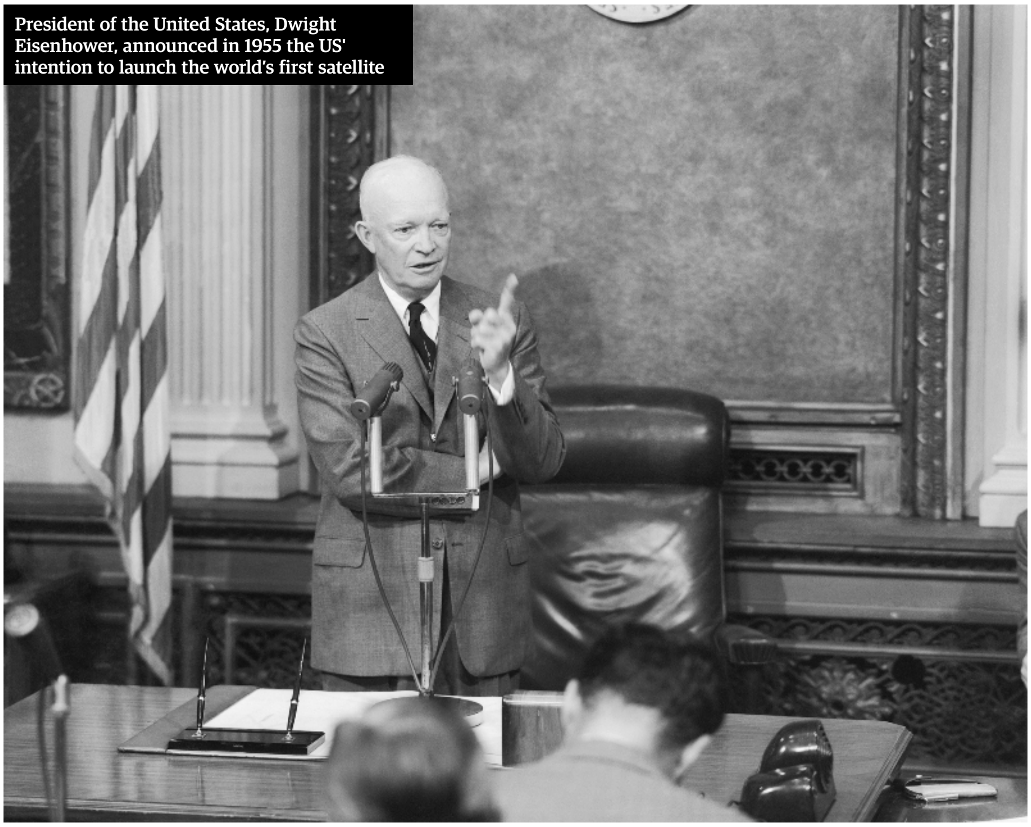
By January 1956 Korolev's vision for the creation of a satellite had been approved by the Soviet Presidium of the Central Committee. Originally constructed under the code name 'Object D', this new form of technology was limited to a weight of between 1,000 to 1,400 kilograms to allow its journey aboard the R-7 rocket, sitting at the head. Several versions of Object D were designed, equipped with the latest in observational technologies. Object D housed receivers and transmitters to transmit measurements and data to stations back on Earth. Aviation technologies were incorporated in order to study areas such as the Earth's gravitational field, shape, ionosphere and space radiation, to name just a few. However, due to the IGY set by the United States, the predicted completion and launch of Object D crossed the window of opportunity, and so a simpler spherical alternative was considered.

'Prosteishy sputnik', or 'simplest satellite', became the Soviets' stand-in satellite. Simplified in size, weight and equipment, the Sputnik satellite, also known as PS, was designed to be completed and launched by the end of 1957. Only 83.6 kilograms in weight and 59 centimetres (23 inches) in diameter, the first Sputnik satellite was made by fusing two aluminium hemispheres only two millimetres thick. Polished to perfection for easy detection, the futurist sphere extended two long antennae, finalising its now-unmistakable appearance. A technological downgrade from its predecessor, Object D, housed in the sphere was a simple radio beacon for telemetry back down to Earth. This simplistic design allowed the Soviet engineers to create a functional satellite well within the window of the IGY deadline. On 4 October 1957 at a Soviet Union testing facility in the Kazakh Republic, history was made with the launch of the Sputnik satellite. Partnered with the R-7 rocket, the elliptical sphere thrust into the atmosphere until escaping the skies into space.

After the rocket successfully escaped the atmosphere, Korolev and his team waited anxiously, ears pointed at the radio receiver. After a few moments, simple beeps sounded from the radio and cut through the tension that filled the air. Signalling



Sputnik's success became a hot topic among the press in both the Soviet Union and the United States


President of the United States, Dwight Eisenhower, announced in 1955 the US' intention to launch the world's first satellite

The third generation of Sputnik satellites was launched in 1960 to study the Earth's magnetic field

> “On 4 October 1957 at a Soviet Union testing facility in the Kazakh Republic, history was made”

the satellite's success, the beeps lasted for around two minutes before losing signal as Sputnik continued on its journey around the Earth. As those first few beeps came through the airwaves, the Soviet Union had secured its place as the leader in space exploration to the world. Met with roaring applause by the Soviet Union, these simple beeps signified not only the satellite's safe arrival into space, but the satellite's position in orbit, mapping the world. Travelling at around 30,000 kilometres (18,641 miles) per hour, Sputnik took 96 minutes to orbit the Earth, lasting three months before burning up on re-entry.

Sputnik mania swept the USSR. Commemorative stamps and even toys of the satellite's journey were made to celebrate its success. This venture into space had awakened the world to the power of the Soviet Union, who now saw themselves as the rightful pioneers of space. Korolev was once quoted as saying: “The Soviet Union has become the seacoast of the universe”.

The once-unthinkable feat of reaching for the stars was now a reality. However, the achievement wasn't seen by all as a testament to mankind, but a threat to their freedom. The announcement of Sputnik's short-lived survival in space was initially met with congratulations in the US by President Eisenhower. However, messages of goodwill soon shifted into a frenzied panic at the potential military threat to their nation, commonly known as the Sputnik crisis. Though it is believed that President Eisenhower and the US government were aware of the Sputnik satellite prior to its launch, the impact it would have on the world was greatly underestimated. What hit the American people was fear. Fear that the Soviet Union may have weaponised space. Fear that America had fallen behind as the world's technological authority they had once been held as. Such a small, insignificant satellite (especially when compared to modern-day creations) had sent a world power into utter disbelief, and fuelled the fire of its space programme. And so the Space Race had officially begun.

The United States achieved its venture into space in January 1958, launching Explorer I. Again, however, the achievement was overshadowed by the success of Sputnik 2, which delivered a dog into space only a few months after the launch of the first Sputnik. Though Sputnik had initially sparked outrage throughout the United States, as a result of its success one of the world's most respected and advanced organisations was born. Fuelled by the fire to regain their technological authority, American officials created the Advanced Research Projects Agency (later renamed DARPA), and in October 1958 the National Aeronautics and Space Administration (NASA) was created to further the work of the National Advisory Committee for Aeronautics, founded in 1915.

The two nations battled it out during the years that followed, with the Soviet Union claiming the record of putting the first man into space and woman into space. Though born from the battlefield, Sputnik's creation was a feat of not only rocket engineering, but that of scientific investigation. It sparked an era of discovery and exploration like no other. Arguably the mascot of the Space Race, Sputnik will forever be seen as a beacon of possibility.

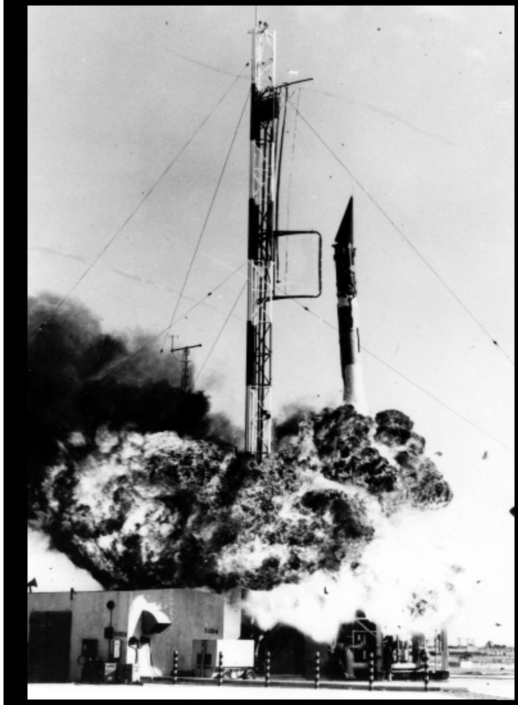
Signalling its survival in space, Sputnik's beeps could be heard on a regular radio, allowing not only the Soviet Union to listen in...

‘FLOPNIK’

ALTHOUGH ACHIEVING SUCCESS IN SPACE IN 1958, THE UNITED STATES' EXPLORER I SATELLITE WAS NOT ITS FIRST ATTEMPT AT REACHING THE STARS

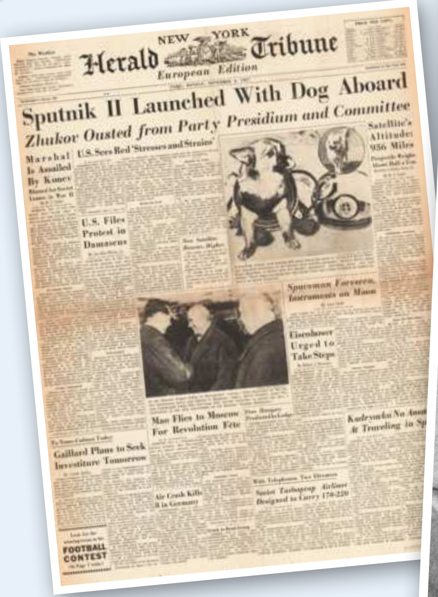
Invigorated by Sputnik's success, America's own artificial satellite, the Vanguard, promised a more advanced analytical prowess to collect data from space. As a counterpart to Sputnik, though behind in the Space Race, Vanguard was set to launch in December of 1957. The long-awaited and highly publicised satellite was America's attempt to regain confidence in the country's ability to rival the Soviet Union. Similar in size and shape to Sputnik, the officially titled ‘Naval Research Laboratory Vanguard TV3’ (Test Vehicle 3) utilised a three-stage Vanguard rocket and was said to be capable of studying the effects of space's environment on the satellite, and the ability to take geodetic measurements of Earth.

However, Vanguard's journey to outer space was cut short. Launching from Florida's Cape Canaveral, the satellite and accompanying rocket only made it just over one metre off the ground before tragedy struck. Unfortunately, due to a fuel tank failure, the rocket and its satellite passenger crashed back down to the ground in a spectacular explosion. It is still unknown as to the exact cause of the rocket's misfortune, though there was speculation burning fuel had entered the fuel system before propellent pressure had been achieved. During the height of the Cold War, this was yet another blow to the US' confidence in its space abilities, with press dubbing the satellite ‘Flopnik’. The failure was not long-lived, however, and by the following March of 1958, the next-generation Vanguard 1 made a successful trip into space.



Flames engulfed the fuel tanks of the Vanguard rocket, causing a massive explosion during launch

© Getty Images



NEW YORK Herald Tribune
European Edition

Sputnik II Launched With Dog Aboard

Zhukov Ousted from Party Presidium and Committee

Satellite's Altitude: 936 Miles

U.S. Files Protest in Damascus

Eisenhower Urged to Take Steps

Mao Flies to Moscow For Revolution Fete

Gaillard Plans to Seek Investiture Tomorrow

FOOTBALL CONTEST

The New York Herald Tribune ran Laika's story on the front page on 4 November 1957, the day after the launch

After undergoing harsh training, Laika was chosen to be the first dog in space

The FIRST COSMONAUT

As the Soviets prepared to send a human into space, a stray dog from Moscow became a national hero

★ Written by Katharine Marsh ★

Moscow was home to many stray dogs in the 1950s, but only one would change the world. Brought in from the cold by scientists, a part Siberian husky, part terrier mongrel was bound for the stars - or at least low-Earth orbit. Named Kudryavka, or Little Curly, she was taken away for training.

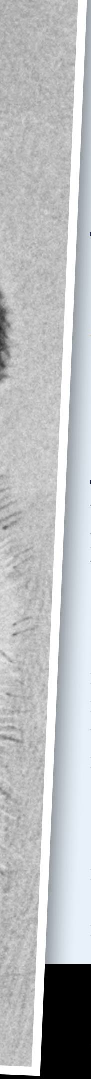
The idea of sending an animal into space wasn't new; both the United States and the USSR had been launching rockets with animals since 1947. However, this would be the first time that an animal would make it into orbit, an idea by Soviet premier Nikita Khrushchev to put his nation one step ahead in the Space Race. The dog would be aboard Sputnik 2, launched just months after the original Sputnik.

Kudryavka wasn't the only dog chosen to undergo cosmonaut training - several others attended alongside her. Only it wasn't as glamorous as most might expect. The dogs - all strays, and all female because of their smaller sizes and the fact that they don't need to lift their legs to urinate, thus taking up more room in a capsule - were placed in small, pressurised cages and trained to eat nutritious gels instead of kibble. Over time, the cages became smaller and smaller. One after another, dogs left the programme.

Eventually three dogs were chosen. Mushka would be the control. Albina was the backup for the mission itself, although it's thought that she wasn't picked for the main event as she had recently given birth. Instead the prized position was given to Kudryavka, supposedly for her resourceful but docile nature and her inquisitive expression. But everyone knew that it wasn't a prize at all - in the short turnaround of the mission, scientists had no time to find a way to bring her back to Earth. Her introduction to the rest of the world was via radio, and it was then that she picked up the more popular name of 'Laika', while the American press referred to her as 'Muttnik'.

The night before the big flight, one of Laika's keepers took her home because he "wanted to do something nice for the dog". Another handler went against the rules by feeding her just before she boarded Sputnik 2. The team knew that they

Laika has been memorialised in a statue that shows her inquisitive nature



> **"The American press referred to her as 'Muttnik'"**

would never see her again - at best, with the oxygen provided, she would survive about a week, and they were sending her up with one day's worth of food.

Sputnik 2 launched on 3 November 1957, Khrushchev's way of celebrating the 40th anniversary of the Russian Revolution. The g-forces reached five times normal gravity levels and the noises terrified the poor dog, who was in a spacesuit that prevented her from moving around. Her heart rate tripled while her breathing rate quadrupled, but she reached orbit alive and completed the first circle of the Earth in about 103 minutes.

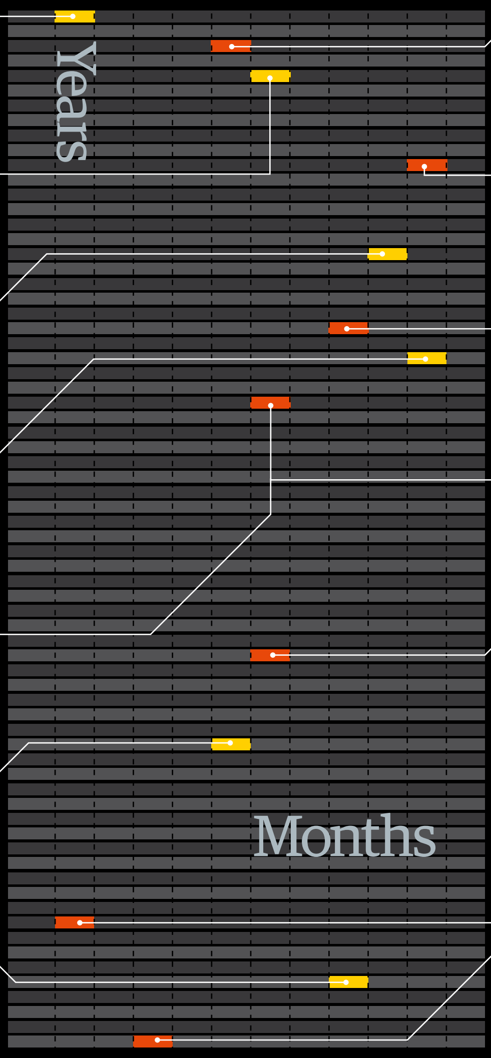
The Soviets made sure the world knew their mission had been a resounding success - Laika had survived and was in orbit. What they neglected to mention was that Laika had died about four hours in, terrified and overheated in a cabin registering about 90 degrees Celsius (194 degrees Fahrenheit). One of her trainers, Oleg Gazenko, later revealed that "the more time passes, the more I'm sorry about it".

Protests were held in London and New York, criticising the treatment of Laika for what turned out to be a suicide mission - but they hadn't really protested any use of animals in spaceflight before. The legacy of the first-ever cosmonaut certainly sits in an ethical grey area - while she was essentially sent into space to die, how many human lives did she save by doing so by testing new technologies and theories about weightlessness? It's impossible to get a black-and-white answer. What we can say for certain is that she created a new benchmark in the Space Race, and it was up to the United States to respond.

80 ₮
MONGOLIA·МОНГОЛ ШУУДАН

Laika has been commemorated on stamps across the world, including this one from Mongolia

ANIMALS IN SPACE THE ANIMAL KINGDOM PAVED THE WAY TO SPACE FOR HUMANKIND



Fruit flies 20 February 1947
First animals sent into space, launched to a 68-mile altitude by a V-2 rocket for a radiation-exposure study. The fruit flies were recovered alive.

Albert II 14 June 1949
Rhesus monkey Albert II rode a V-2 rocket to an altitude of 83 miles, but died on impact with the ground after suffering a parachute failure.

Tsygan and Dezik 22 July 1951
The two dogs reached an altitude of 62.7 miles and became the first living 'higher' organisms to be recovered alive following a spaceflight.

Laika 3 November 1957
Although she was not the first dog to enter space, Laika - a stray, picked up on the streets of Moscow - was the first living creature to enter orbit.

Félicette 18 October 1963
Paris street-cat Félicette is the only feline to have launched into space and returned alive, completing a 15-minute suborbital flight.

Tortoises 14 September 1968
Along with other biological organisms, two Horsefield's tortoises were the first living creatures to orbit around the Moon and return safely to Earth.

Bullfrogs 9 November 1970
Launched on the Orbiting Frog Otolith mission, two were flown to examine their inner ears and understand more about motion sickness.

Anita and Arabella 28 July 1973
These two garden spiders took a long time to adapt to weightlessness and spun thinner webs than on Earth. Anita and Arabella died during the mission.

Mummichog 28 July 1973
Two mummichog fish flew aboard America's Skylab space station, initially swimming in tight circles before adapting to weightlessness.

Newts 10 July 1985
Ten newts flew aboard the Bion 7 spacecraft. Part of their front limbs were amputated to allow studies of regeneration in space.

Jellyfish 5 June 1991
Almost 2,500 moon jellyfish flew aboard the shuttle in order to study their nervous systems and the impact of weightlessness on their swimming.

Nematodes 1 February 2003
A live group of nematodes, or roundworms, remarkably survived the destruction of shuttle Columbia, which broke up during re-entry.

Tardigrades 14 September 2007
During Europe's Foton-M3 mission, tardigrades were able to survive ten days of exposure to space with only their natural protection.

Mice 14 April 2015
Delivered to the ISS aboard a Dragon cargo ship for studies to examine the effects of weightlessness on organisms where physical activity isn't an option.

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RISE of the SPACE AGE

Shadowed by fear of war, the early days of exploration showed humanity at its most bold

Written by Ben Evans

Sixty-one years ago, the world gazed at the sky and listened through shortwave radio receivers with fascination and fear. For millennia, humans had clung to the Earth's surface, only recently having mastered the long-held dream of flight and with scant awareness of what lay beyond the thin veil of the atmosphere. But, on 4 October 1957, our sense of place in the cosmos changed forever. Over three weeks, a steady 'beep-beep' transmission from Sputnik 1 – the first artificial satellite – heralded the dawn of the Space Age. Yet the euphoria of conquering space was met by harsh Cold War reality, as Russia and America sought to deliver weapons of enormous destruction across intercontinental distances.

For something that changed the world, Sputnik 1 was an unremarkable icon. It was a polished metal sphere, 23-inches across, with four antennae to broadcast radio pulses at 20.005 MHz and 40.002 MHz, easily audible to amateur radio listeners. Circling the globe at 65-degrees of inclination, its flight path carried it over virtually the entire inhabited Earth, completing an orbit every 96.2 minutes. Its signal vanished when its batteries died, and the 184-pound satellite burned up in the atmosphere in January 1958.

Thus began the Space Race between the capitalist United States and the communist Soviet Union to attain mastery over the heavens. Following the World War II, both nations used captured German scientists and rockets (including the infamous V-2) to further their ambitions of building intercontinental ballistic missiles to establish technological and ideological supremacy over the other. Juxtaposed against this bellicose stance was the 1957-1958 International Geophysical Year, a concerted 18-month campaign of Earth science research. In the summer of 1955, the United States and the Soviet Union pledged to launch a satellite during the IGY.

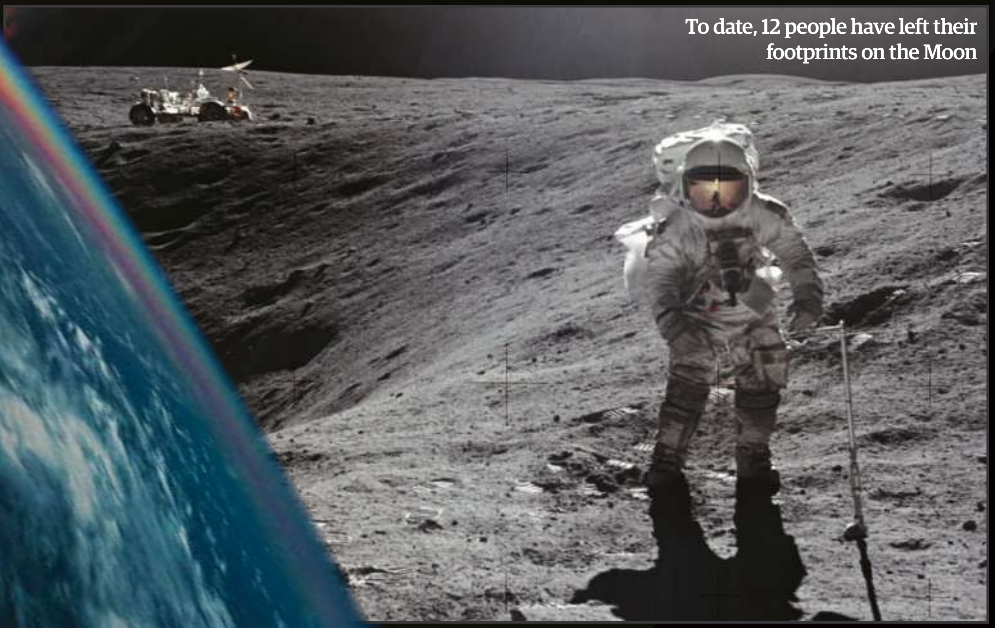
Politically, Sputnik 1 was a great shock, and demolished Western perceptions of Russia as a backward nation made up of potato farmers and inept politicians. Science-fiction writer Arthur C. Clarke reflected that on 4 October 1957, the United States became a second-rate world power, while economist Bernard Baruch praised the Soviet "imagination to hitch its wagon to the stars" and stressed that American paranoia was well founded. During his 1960 presidential campaign, John F. Kennedy played into this palpable sense of national dread by claiming that Soviet hegemony in space could someday afford them control of the Earth.

After the 'Sputnik Crisis', political figures increasingly spoke of a 'gap' in missile-building technology, with the United States falling behind the Soviet Union. Indeed, the Soviets created the world's first intercontinental ballistic missile – the R-7 – and test flew it across a distance of 3,700 miles, before using a modified version to launch Sputnik 1. Remarkably, the same basic rocket is still used to launch satellites and humans today. The missile gap was promulgated by the Gaither Report in November 1957, which recommended a significant strengthening of US military might. Its figures were exaggerated, but the fiction of a missile gap galvanised America into forming NASA in October 1958, and accelerated the development of rockets to send men into space.

America's ascendancy into space began with disappointment. In December 1957, a Vanguard rocket exploded on the launch pad, triggering a media frenzy. Journalists mocked it as 'Kaputnik', while Soviet delegates to the United Nations tauntingly wondered if the United States needed their aid as an "undeveloped nation". Finally, on 31 January 1958, Explorer 1 became America's first successful satellite. Six weeks later, it was followed by Vanguard 1, disparagingly nicknamed "the grapefruit" by Soviet Premier Nikita Khrushchev. However, the smallness of these early satellites actually belied their rather advanced scientific capabilities. Explorer 1 discovered the Earth's Van Allen radiation belts, while Vanguard 1 remains the oldest man-made object still in orbit today.

The benefits of satellites for a range of applications – from communications to reconnaissance and navigation to scientific research – had long been recognised, and in December 1958, the first test of a relay was used to broadcast Christmas greetings from US President Dwight D. Eisenhower. Two years later, Echo 1 became the world's first passive communications satellite, followed by Telstar, which transmitted television pictures, telephone calls and telegraph images, as well as a live transatlantic feed between the United States and Belgium.

It was Arthur C. Clarke who first widely disseminated the idea of putting satellites into 'geostationary' orbit, more than 22,000 miles above the Earth, matching the planet's rotation for worldwide communications. Syncom 3 was the first to reach this high orbit, relaying images from the 1964 Summer Olympics in Tokyo. This laid the foundation for hundreds more communications satellites, which continue to deliver telephone, television, radio and internet services.

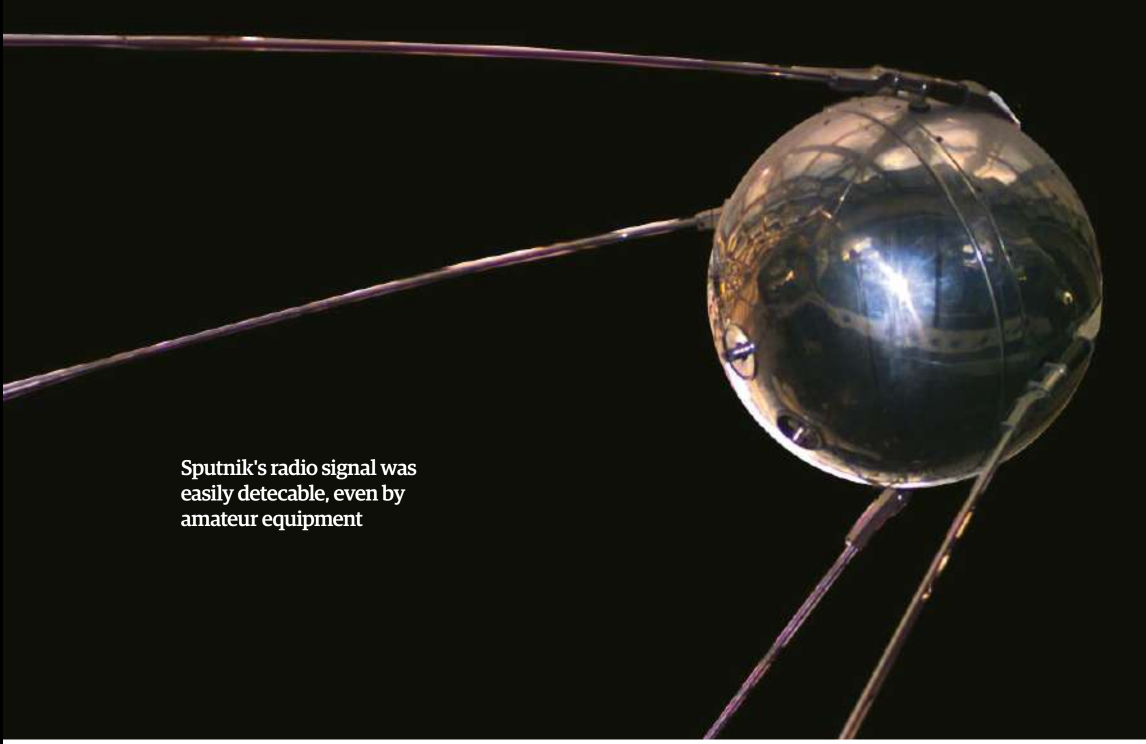


To date, 12 people have left their footprints on the Moon

© NASA; Getty/Bjorn Holland

THE GREAT SPACE RACE

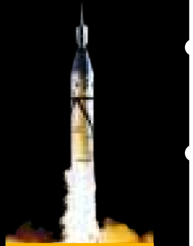
FROM TINY SATELLITES TO BOOTS ON THE MOON, HUMANITY TOOK GREAT STRIDES IN A SINGLE DECADE


Sputnik's radio signal was easily detecable, even by amateur equipment

UNITED STATES | 1955 | SOVIET UNION

4 October 1957 Sputnik 1, world's first artificial satellite.

3 November 1957 Sputnik 2, carried first living creature into orbit.



31 January 1958 Explorer 1, America's first satellite.

12 September 1959 Luna 2, first mission to crash-land on the Moon.

1960

4 October 1959 Luna 3, first images of the far side of the Moon.

5 May 1961 Alan Shepard, America's first man in space.

12 April 1961 Yuri Gagarin, first man in space.

20 February 1962 John Glenn, America's first man to orbit the Earth.

16 June 1963 Valentina Tereshkova, first woman in space.

3 June 1965 Ed White, America's first spacewalk.

15 December 1965 Gemini 7 and 6, first rendezvous in space.

18 March 1965 Alexey Leonov, first spacewalk.

16 March 1966 Gemini 8, first docking in space.

24 December 1968 Apollo 8, first mission to orbit the Moon.

21 July 1969 Apollo 11, first piloted landing on the Moon.

1970

> "The pendulum shifted in the mid-1960s, and truly America took the lead"

Of course, the Cold War inspired less peaceful activities, too, and planning for reconnaissance satellites was set in motion early in the Space Age. However, it was only after the infamous shootdown of Gary Powers' U-2 reconnaissance aircraft in May 1960 that the need for military eyes in space became commonplace. In August of that year, Discoverer 13 became the first satellite to return an object safely to Earth, in the form of a classified film canister. Less than two weeks later, the Soviets brought their Korabl-Sputnik 2 spacecraft, carrying the dogs Belka and Strelka, safely back home. It was the first time that living creatures had been launched into orbit and returned alive.

Sending living creatures, and eventually humans, into space was an important driving force. In November 1957, the Soviets launched Sputnik 2, carrying a dog, Laika. Several animals had already flown above the 62-mile-high 'Kármán line' - the internationally recognised boundary for the edge of space - but three-year-old Laika was first to actually achieve orbit. Following a stressful launch, Laika died within hours when the cabin overheated. Her legacy is that she unmasked some of the unknowns about the survivability of launch, orbital acceleration and the effects of weightlessness. Laika laid the groundwork for the 108-minute orbital flight of Yuri Gagarin, the first man in space, on 12 April 1961.

If Sputnik 1 shocked the world, then Gagarin's mission shocked it again, particularly as it occurred only months into the administration of President John F Kennedy. Matters worsened when CIA attempts to overthrow Fidel Castro failed, leaving Kennedy humiliated, and in need of a means to re-establish his nation's prestige. Although Alan Shepard became America's first man in space on 5 May 1961, his Redstone booster was only capable of a 15-minute suborbital flight. Not until the following year did John Glenn - riding the larger, more powerful Atlas rocket - actually achieve orbit.

Despite such limited spaceflight experience, Kennedy told a joint session of Congress that he intended to direct the United States to land a man on the Moon before the end of the decade. It was a challenging gamble, since lunar exploration had been pioneered by the Soviets. In January 1959, Luna 1 became the first man-made object to reach the Moon, measuring the solar wind, and eventually entering heliocentric orbit. Before the year ended, Luna 2 had been intentionally crashed into the surface, and Luna 3 returned the first photographs of the Moon's far side, never before seen by human eyes. On 3 February 1966, a Soviet spacecraft, Luna 9, performed the first soft landing on another celestial body.

Russia also held the advantage in human space exploration, flying cosmonauts into orbit for several days, sending the first woman into space, launching the first multi-person spacecraft and executing the world's first spacewalk. However, the pendulum shifted in the mid-1960s, and America took the lead, flying longer missions, performing spacewalks and docking with other spacecraft. Its investment in Kennedy's goal peaked at 5 per cent of the

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federal budget. Meanwhile, the Soviets suffered the premature death of their chief rocket designer, Sergei Korolev, and the advantage slipped from their fingers. Yet the dangers of space exploration were ever-present. America lost three Apollo astronauts in a launch pad fire in January 1967 and, just three months later, a Russian cosmonaut plunged to his death when the parachutes on his descending Soyuz spacecraft tragically failed to open.

In spite of the emphasis on reaching the Moon, both nations also turned their attention further afield, with the United States completing the first flyby of Mars with Mariner 4 in July 1965. The spacecraft's photographs revealed a hostile world, with no evidence of wind or water erosion, and a virtual absence of a magnetic field. Soviet missions to the Red Planet were more troubled: three exploded during launch, and another was lost during its outward journey. Mariner 2 flew past Venus in December 1962, while Russia's Venera 3 was first to crash-land on the planet's surface in March 1966. A year later, Venera 4 became the first spacecraft to take direct measurements from another planet's atmosphere, revealing carbon dioxide as Venus' main constituent.

The race to the Moon continued unabated. In November 1967, America test flew its Saturn V lunar rocket for the first time, and the following September, Russia launched the Zond 5 spacecraft around the Moon, carrying a payload which included mealworms, wine flies, plants and a pair of tortoises. They became the first living creatures to venture into deep space, visit our closest celestial neighbour and return safely to Earth.

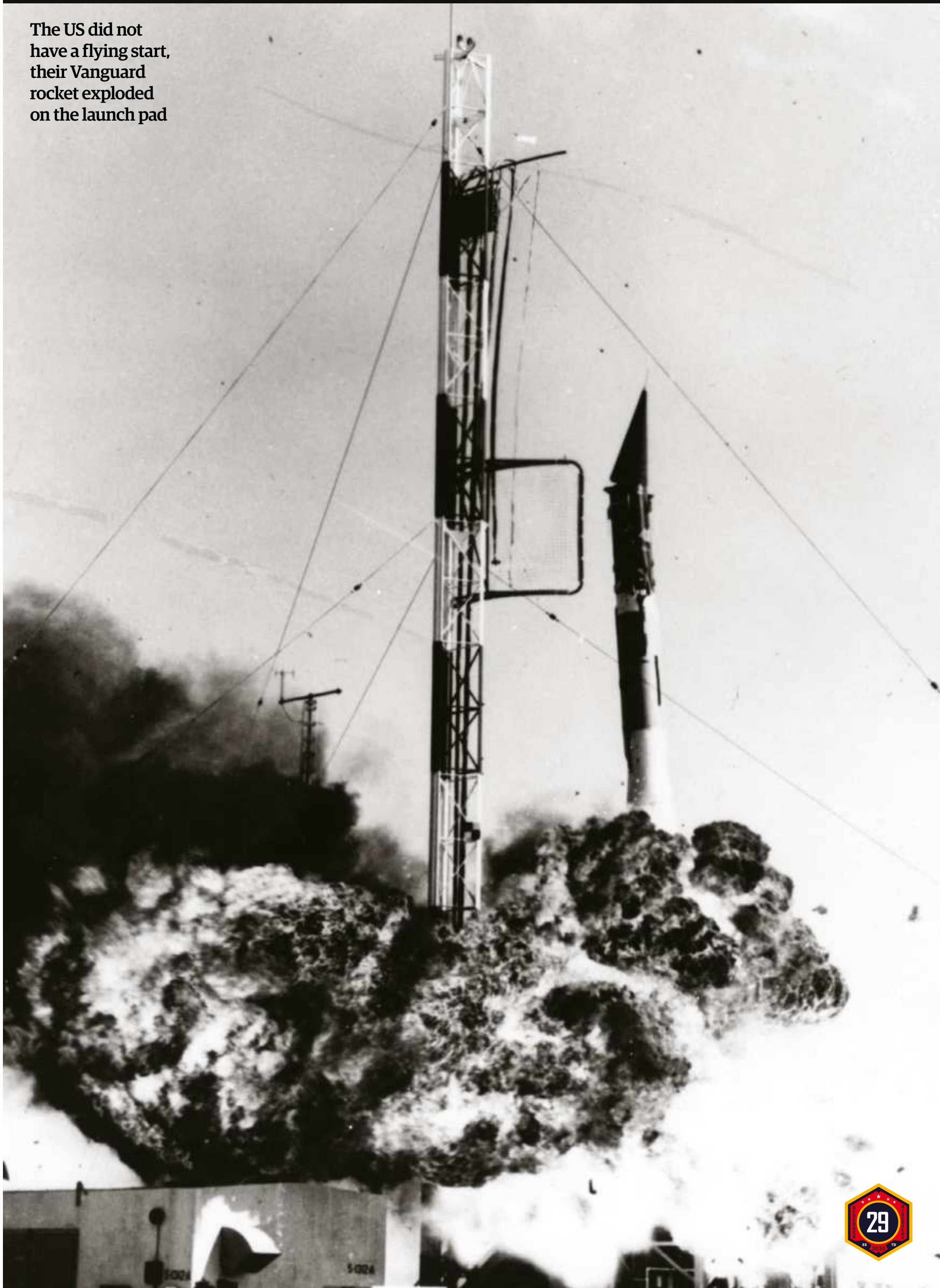
As the end of the decade approached and the final lap of the space race began, CIA intelligence hinted a large Soviet rocket, the N-1, was undergoing final preparations to send a pair of cosmonauts around the Moon. Reconnaissance satellite imagery showed the rocket on its launch pad and, in August 1968, America hurriedly moved to upgrade Apollo 8 from an Earth-orbital flight to a lunar voyage. In just four months, the mission rose from the drawing-board to reality, and astronauts Frank Borman, Jim Lovell and Bill Anders became the first men from Earth to settle into orbit around the Moon.

The N-1, meanwhile, suffered two catastrophic failures in February and July 1969, eliminating the last remaining Soviet hope of somehow getting cosmonauts onto the lunar surface before Neil Armstrong and Buzz Aldrin. Another unmanned spacecraft, Luna 15, sought to tame the impending American triumph by bringing some lunar soil back to Earth, but it ignominiously crashed into the Moon a few hours after Armstrong and Aldrin landed at the Sea of Tranquility.

With the space race won, political attitudes changed. The Soviets refocused their attention on building long-term space stations in Earth orbit, while America developed the shuttle as a more cost-effective means of reaching space.

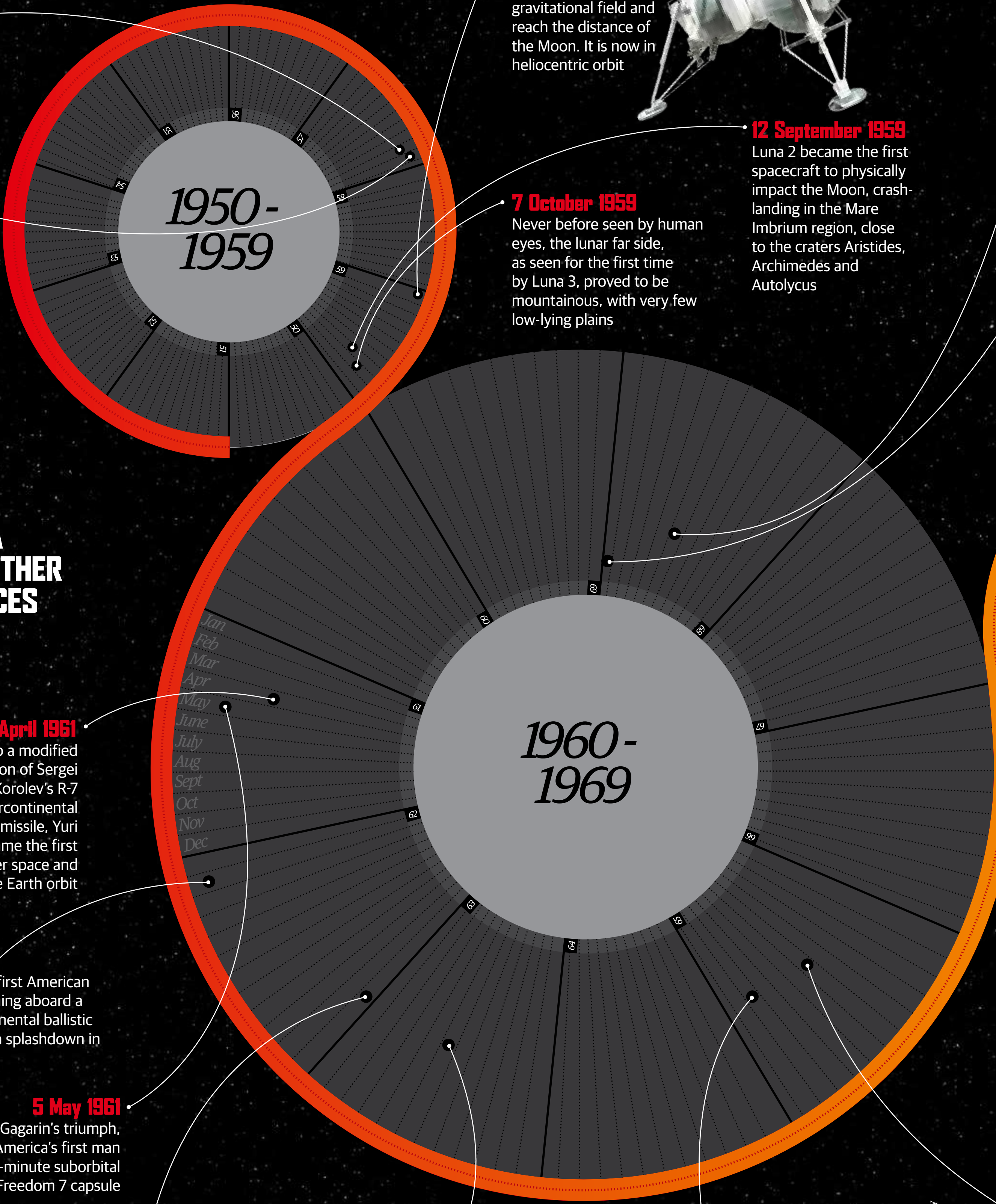
Eventually, the two former foes united their efforts in today's International Space Station. And aboard that station on the 60th anniversary of Sputnik 1's success, astronaut Joe Acaba was filled with wonder for the past and excited hope for the future. "Amazing to be on Space Station and reflect on how far we've come," he tweeted. "What will the next 60 years bring us?"

It's argued the US eventually overtook the USSR in the Space Race


The US did not have a flying start, their Vanguard rocket exploded on the launch pad

SPACE AGE TIMELINE

THE US AND RUSSIA PRESSURED EACH OTHER INTO GREAT ADVANCES



4 October 1957
Sputnik 1, the world's first artificial satellite, spent three months in space and travelled 43 million miles and 1,440 orbits of the Earth

3 November 1957
Launch of the dog Laika, the first living creature to enter orbit around the Earth. She died within hours, when the cabin of her Sputnik 2 satellite overheated

2 January 1959
Launch of Luna 1, the first spacecraft to depart Earth's gravitational field and reach the distance of the Moon. It is now in heliocentric orbit

12 September 1959
Luna 2 became the first spacecraft to physically impact the Moon, crash-landing in the Mare Imbrium region, close to the craters Aristides, Archimedes and Autolycus

7 October 1959
Never before seen by human eyes, the lunar far side, as seen for the first time by Luna 3, proved to be mountainous, with very few low-lying plains

12 April 1961
Atop a modified version of Sergei Korolev's R-7 intercontinental ballistic missile, Yuri Gagarin became the first human being to enter space and complete a single Earth orbit

20 February 1962
John Glenn became the first American to orbit the Earth, launching aboard a modified Atlas intercontinental ballistic missile and returning to a splashdown in the Atlantic Ocean

5 May 1961
Three weeks after Gagarin's triumph, Alan Shepard became America's first man in space. He flew a 15-minute suborbital voyage aboard the Freedom 7 capsule

14 December 1962
Mariner 2 became the first spacecraft to successfully encounter another planet when it flew within 18,700 miles of Venus, revealing thick atmospheric clouds

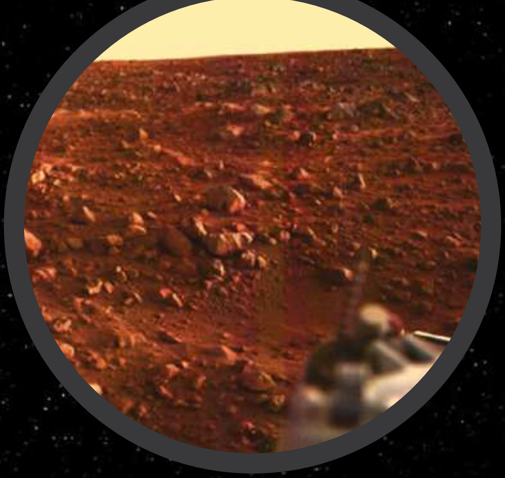
16 June 1963
Former factory worker Valentina Tereshkova was hurriedly trained as part of a propaganda campaign by the Soviet Union to secure a record for the first woman in space

18 March 1965
For 16 minutes, Alexey Leonov floated in the vacuum of space, protected only by his pressurised suit. In doing so, he became the world's first spacewalker

© NASA; Adrian Mann; Chinese Space Agency

20 July 1969
After millennia of gazing upward at the Moon, the space race officially ended when Neil Armstrong and Buzz Aldrin triumphantly set foot on the Sea of Tranquillity

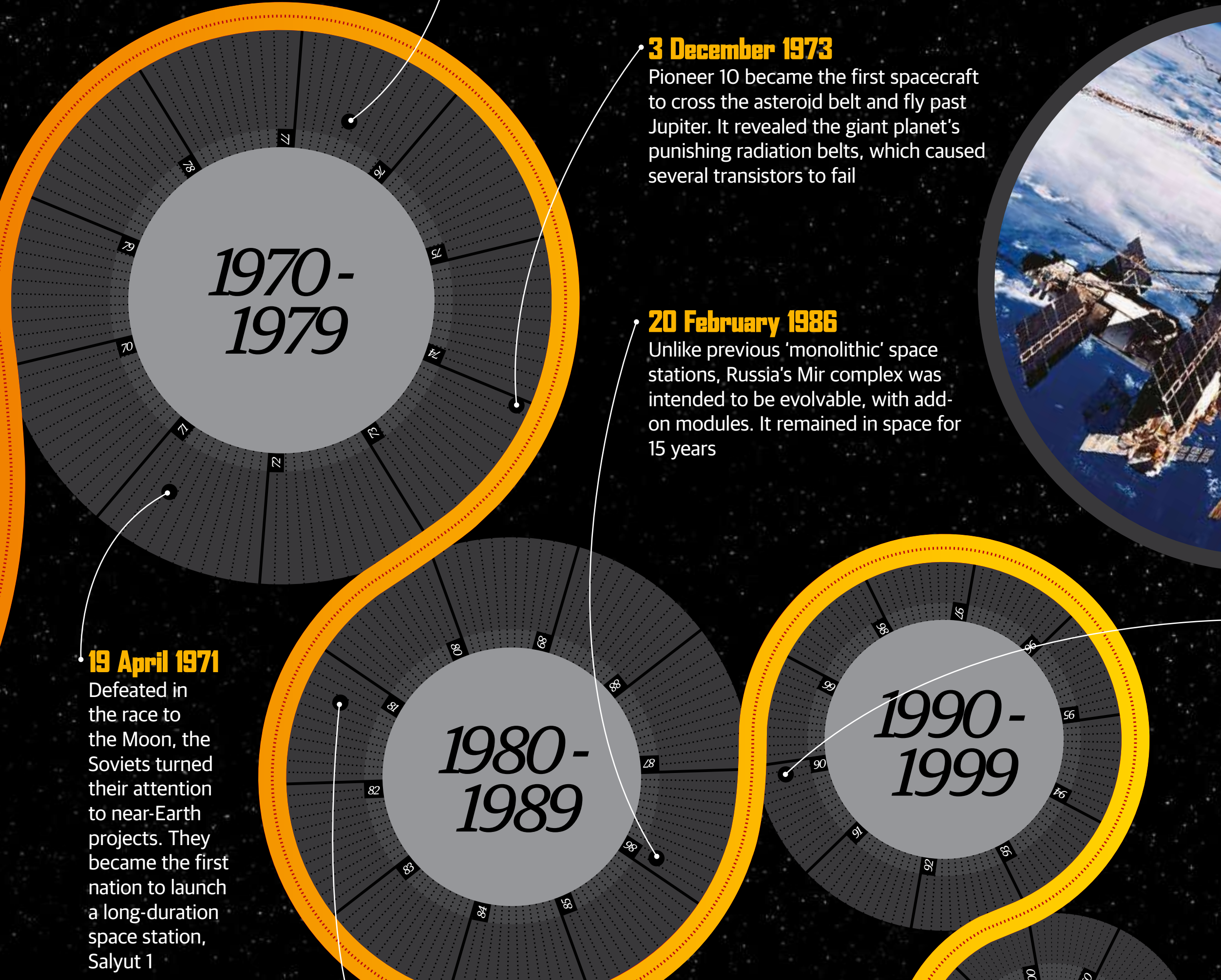
24 December 1968
On Christmas Eve 1968, Apollo 8 astronauts Frank Borman, Jim Lovell and Bill Anders observed 'Earthrise' from behind the limb of the Moon, for the first time



20 July 1976
Seven years after the first manned Moon landing, Viking 1 became the first spacecraft to soft-land on the surface of Mars and successfully completed its mission

3 December 1973
Pioneer 10 became the first spacecraft to cross the asteroid belt and fly past Jupiter. It revealed the giant planet's punishing radiation belts, which caused several transistors to fail

20 February 1986
Unlike previous 'monolithic' space stations, Russia's Mir complex was intended to be evolvable, with add-on modules. It remained in space for 15 years



19 April 1971
Defeated in the race to the Moon, the Soviets turned their attention to near-Earth projects. They became the first nation to launch a long-duration space station, Salyut 1

14 February 1990
From the very edge of the Solar System, Voyager 1 acquired a 'family portrait', showing six of the then-known planets, minus Mercury, Mars and the dwarf world Pluto

15 July 1965
Mariner 4 became the first spacecraft to successfully observe Mars, returning the first-ever images from deep space. It revealed the planet as cratered and geologically dead

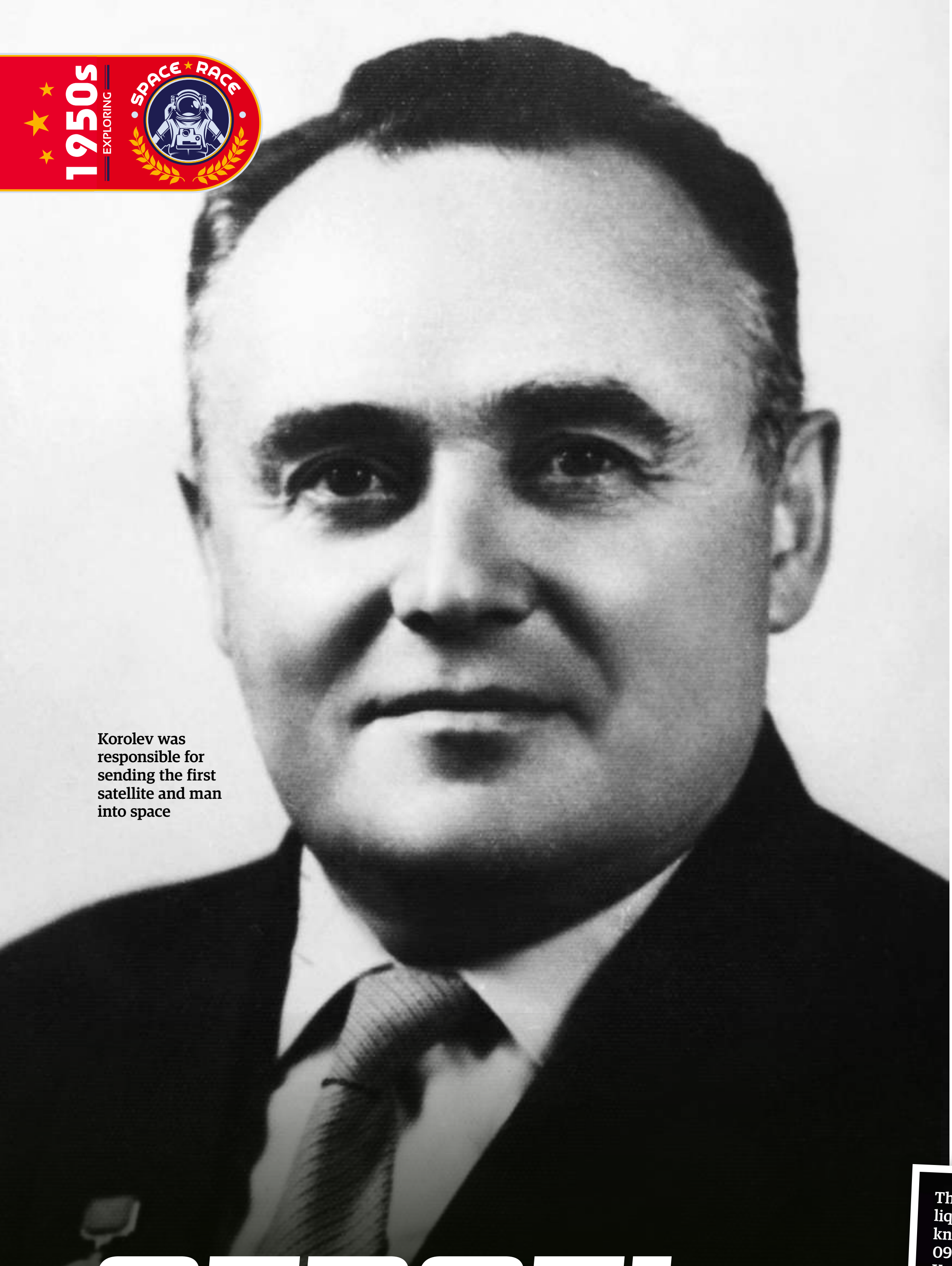
12 April 1981
STS-1, maiden voyage of Columbia, represented the first flight of a reusable winged orbital spacecraft with humans aboard. It marked the dawn of a 135-flight career for the shuttle fleet

15 October 2003
Taikonaut Yang Liwei became the first Chinese spacefarer when China launched the Shenzhou 5 spacecraft, and became the third nation to launch its own personnel into orbit

SERGEI KOROLEV

Meet the engineer who placed the Soviet Union in first place in the race towards space

Written by Scott Dutfield



Korolev was responsible for sending the first satellite and man into space

Born on 12 January 1907, in Zhytomyr modern-day Ukraine, Sergei Korolev was introduced into the world of engineering at a young age by his step-father, an engineer and mechanic. Like so many future cosmonauts and engineers, Korolev became a keen aviation enthusiast as a child. Designing his first glider at only 17, the future pioneer was admitted to the Kiev Polytechnic Institute in 1924. There he thrived for two years studying aeronautical engineering, paving the way for his transfer to the prestigious Moscow Bauman High Technical School, Russia's most accomplished school for engineering. Once among the nation's finest, Korolev first met the man who would later play a vital role in his now celebrated success, Andrei Tupolev, an aeronautical engineer and lead designer the former USSR's military aircraft.

During his time at Baumen, Korolev's interests in flight engineering shifted into the theoretical. The concept of rocket propulsion was still in its infancy and not yet been realised in the Soviet Union. Just one year after graduating Baumen in 1930, Korolev founded the Group for Investigation of Reactive Motion (GIRD) to investigate the future potentials of rocketry. By 1933, the group of expert engineers had created and launched the USSR's first liquid-fluid rocket, known as GIRD-09. Though a triumph in the USSR, Korolev's rocket was not the world's first. In fact, American engineer Dr Robert H Goddard successfully launched his rocket in 1926, and Germany's Society of Spaceship Travel (VfR) was developing its own large-scale version.

Seeing the potential for use in military combat, the Soviet military integrated Korolev, his work and the GIRD into the state-run Reaction Propulsion Scientific Research Institute (RNII). Now with the backing of the military, Korolev and his team utilised their resources to develop missile weaponry, and in 1936 they created the Soviets' first rocket-powered glider, the RP-318.

The Soviets' first liquid-fuelled rocket, known as the GIRD-09, was created by Korolev in 1933

Although on an astronomical professional trajectory, Korolev's success was temporarily cut short at the hands of fearsome dictator Joseph Stalin. During Stalin's purges in 1938, Korolev was falsely denounced to the NKVD, the communist secret police, and the 31-year-old aerospace engineer was sentenced to ten years of forced labour. The first few months of his sentence were spent in transit in the prison vessel Magadan aboard the Trans-Siberian railway, before reaching the Kolyma gold mines, one of Stalin's Gulag labour camps.

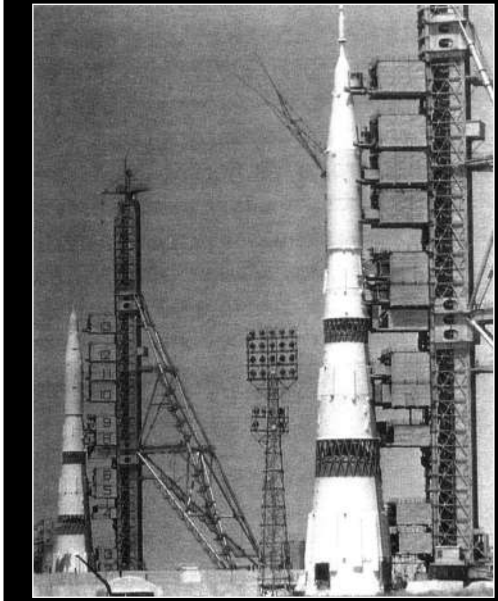
UP IN FLAMES

AFTER HIS DEATH, KOROLEV'S WORK TO PUT MAN ON THE MOON ENDED IN DISASTER

Throughout his lifetime, Korolev had taken strides in the world of space travel, and he is often referred to as the father of the Soviet Space Programme for his work with the R-7 rocket. However, what was hoped to be his crowning glory became the country's greatest space-age shortfall.

Up to the early 1960s, the Space Race was being led by the Soviets, and Korolev was instrumental in this as he was creating a spacecraft capable of soft landing on the moon known as the N-1 rocket. But the US was right behind him, trying to put man on the Moon by 1970 thanks to the development of the Saturn V booster. Both rockets showed promise to be the first to make the milestone, but sadly Korolev passed away before the N-1 was ready for launch.

Throwing the programme into disarray, the N-1 didn't make its first launch attempt until 1969, two years after the Saturn V's first successful launch. The attempt was a failure and the rocket fell in flames, as did the second. The same year, Saturn V crossed the finish line to reach the Moon. After further two attempts to successfully launch the N-1, which again ended in failure, the programme was cancelled – the Soviets had to admit defeat to the Americans.



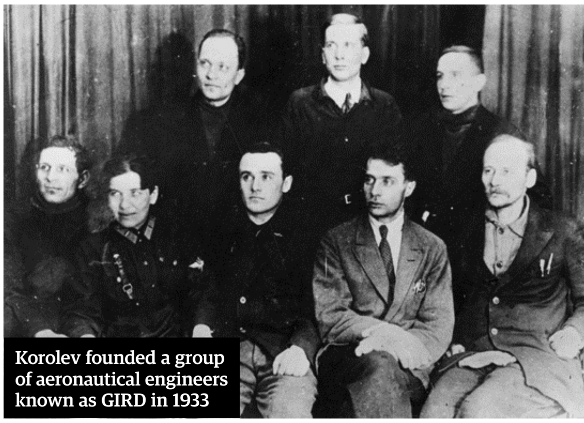
On the eve of the Saturn V's success, the N-1 makes an attempt to reach to the stars

As World War II got underway, the need for advanced military weapons had come to the fore. Thanks to his engineering prowess, Korolev was drafted into a Soviet organisation to put his skills to the test. Joining one of the prison's design bureaus – which were known as Sharaska – a previous acquaintance, Andrei Tupolev, now also a prisoner and the leader of the bureau, requested his services. During his time in the bureau, Korolev assisted in the developed of several military weapons and vehicles, including the Tu-2 bomber plane.

Once the war had ended, Korolev was released from custody and later appointed chief constructor for the development of an intercontinental ballistic missile (ICBM). Advanced in its technology and fatal during the war, German engineers had already created a similar rocket with the V-2. Intrigued by the V-2's military and space travel capabilities, Korolev was sent to Germany to investigate and improve upon the designs. In 1953, he had gained approval from the Council of Ministers to develop the world's first ICBM, the R-7. Though capable of intercontinental warfare, the missile was instead put to use to break through the Earth's atmosphere and deliver the world's first ever artificial satellite, Sputnik, into space in 1957. As a roaring triumph for the Soviet Union, the development of Korolev's R-7 solidified the USSR as the frontrunners in a quickening space race with the US.

Work continued and in 1959, Korolev developed and launched several lunar probes to the Moon, but the country's ultimate goal to had yet to be achieved. Now toe to toe with American engineers to be the first to put man into space, it was Korolev's R-7 that again rose to the challenge, sending up cosmonaut Yuri Gagarin to complete one orbit of the Earth in 1961. Galvanised by his success, work began on developing a vehicle capable of the ultimate goal: landing man on the lunar surface.

However, for Korolev and indeed the entire country, this was never realised. During a minor operation in 1966 Korolev died, and it's thought that this was the result of years of damage to this immune system during his time in the Gulag. During his lifetime, Korolev and his work remained a state secret, known only to the world upon his death. As such, his work has been celebrated by the nation including the naming of a city in his memory, craters on both the Moon and Mars, and even an asteroid.



Korolev founded a group of aeronautical engineers known as GIRD in 1933

ЛЕВ С. П. 1906 г

During the Great Purge of 1938, Korolev was arrested and sentenced to hard labour

Korolev began his career developing gliders when he was just 17

© Getty Images, NASA

The ROCKET MAN

Wernher von Braun started his career as a Nazi scientist, and ended it after putting the USA on the Moon

Written by April Madden

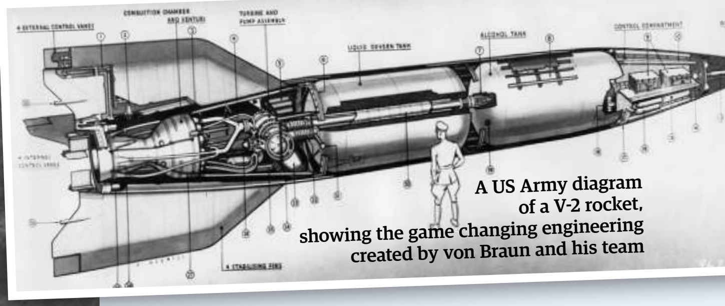
Apollo 11 lifting off on the Saturn V rocket that was von Braun's brainchild and lifelong dream

Wernher von Braun was a leading light in NASA's rocketry programme. His work put man on the Moon

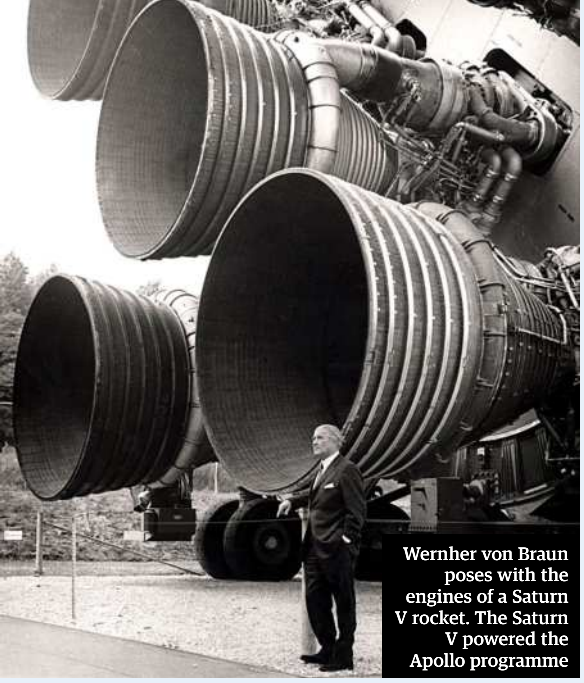
The German civilian on the bicycle approached tentatively. It was 2 May 1945 in a small Austrian village. Far away in Berlin, Nazi Germany was falling to the Allied forces. That was where the action was. There was little chance of glory for a private of the US 44th Infantry in this backwater. Then the German spoke, hesitantly, in halting English. "Hello? My name is Magnus von Braun. My brother invented the V-2. We want to surrender."

US High Command were delighted. The man's brother was Wernher von Braun, leading light in the Nazi weapons development programme. The V-2 rocket he had invented was extraordinary; an unmanned, guided ballistic missile, capable of delivering death from 200 miles away. There were even whispers that his technology could broach the edge of space itself. They may have been mere rumours, but the Americans were confident that their new guest was soon going to tell them everything that they wanted to know. And he did.

Wernher von Braun was born on 23 March 1912 in Wirsitz, a small town in what is now Poland. His family were upper class and well-to-do; his father was a government minister during the Weimar Republic, and the family lived in Berlin. Wernher was a clever boy – he played piano and cello and had early ambitions to be a composer. But when his mother bought him a telescope, he realised his destiny lay with the stars. In 1924 at the age of 12, he was arrested after blowing up a toy car in a busy Berlin street. He'd attached fireworks to it, in a schoolboy attempt at making a rocket. Despite his precocity, however, Wernher was failing mathematics and physics, until he read Hermann Oberth's book *By Rocket into Planetary Space*, which taught him their importance. Years later, he explained: "Hermann Oberth was the first, who when thinking about the possibility of spaceships, grabbed a slide-rule and presented mathematically analysed concepts and designs… I, myself, owe to him not only the guiding-star of my life, but also my first contact with the theoretical and practical aspects of rocketry



A US Army diagram of a V-2 rocket, showing the game changing engineering created by von Braun and his team



Wernher von Braun poses with the engines of a Saturn V rocket. The Saturn V powered the Apollo programme

Taken during the launch of Apollo 11, this photo shows von Braun during the launch of the mission that would see his dream of sending a manned rocket to the Moon come true

and space travel". Enthusiasm renewed, he began pursuing the subjects in earnest, and excelled at them. He studied physics, chemistry and astronomy, and was working on his doctorate in physics when the Nazi Party came to power.

Weapons research and development was forbidden to Germany under the terms of the Treaty of Versailles that had ended World War I, but for some reason, rocketry had been overlooked, so von Braun could legitimately study it. His doctoral research was immediately classified by the armed forces, and ostensibly von Braun was given little choice about his absorption into their ranks. He later claimed that he was effectively ordered to join both the SS and the Nazi Party, and he was certainly given no choice over being moved to a development facility in the industrial area of Peenemünde, where he began to study and develop rocket technology in earnest. When a colour movie of his V-2 rocket was presented to Adolf Hitler, the enthusiastic Führer personally made von Braun a professor. Despite this success, he was aware that the paranoid Nazi command could change its mind at any time. He was arrested in 1944 – an informer had claimed that he'd complained at a dinner party that he wasn't able to work on a spaceship – and held for two weeks, until his supervisors secured his release.

Aware that the war effort was now going badly for Germany, von Braun spoke to other staff at the Peenemünde facility and gave them a stark choice: surrender to the Americans or to the Soviets. The German rocket team, aware that their SS guards had orders to kill them if any enemy approached, decided to take a chance on the USA. When they were dispersed into the Austrian hills during the last days of the war, they took their chance to run straight into the Americans' arms. The team surrendered en masse; Wernher von Braun was placed under the care of US and British troops at Kransberg Castle in Hesse, where German scientists were being debriefed. Despite his surrender to the US, it's alleged that von Braun was initially debriefed by a British team that included Britain's leading rocket engineer LS Snell, inventor of the Concorde supersonic jet engine. What exactly von Braun discussed with the British has never been revealed.

Evacuated to the US as part of Operation Paperclip, in which the US offered new lives to Nazi scientists in exchange for their continued research, von Braun and his team eventually ended up in Fort Bliss, Texas. Jokingly referring to themselves as "prisoners of peace", they continued their work, despite a lack of finance for both their research and their living quarters. The Korean War saw a change in their fortunes: they were transferred to Alabama, where they began work on the famous Redstone rocket. Frustratingly though, throughout the 1950s, the Soviet Union, inspired by von Braun's V-2 rockets, were always one step ahead of him. When the Soviets won the first stage of the Space Race by putting the Sputnik satellite in orbit, the US created its state-funded space agency, NASA. Wernher von Braun was transferred to the nascent agency in 1960, with the aim of putting the Americans back in pole position. Despite finally being able to work on his dream project – a rocket bound for space – von Braun was apparently overly cautious. His focus on fixing technical issues before the test flights that would allow his rocket design to be certified safe for human flight delayed NASA's efforts, resulting in the Soviets being the first to put a man in space.

This photograph was taken shortly after von Braun surrendered to American forces in 1945

Wernher von Braun did eventually achieve his goal – his Saturn V rockets put the Apollo missions on the Moon – but despite reaching the rank of Deputy Associate Administrator for Planning at NASA, he always felt that his vision for conquering the stars was at odds with the American government's waning interest in the space programme once the Moon had been reached. He retired from NASA in 1972 and died in 1977.

NAZI CONTROVERSY

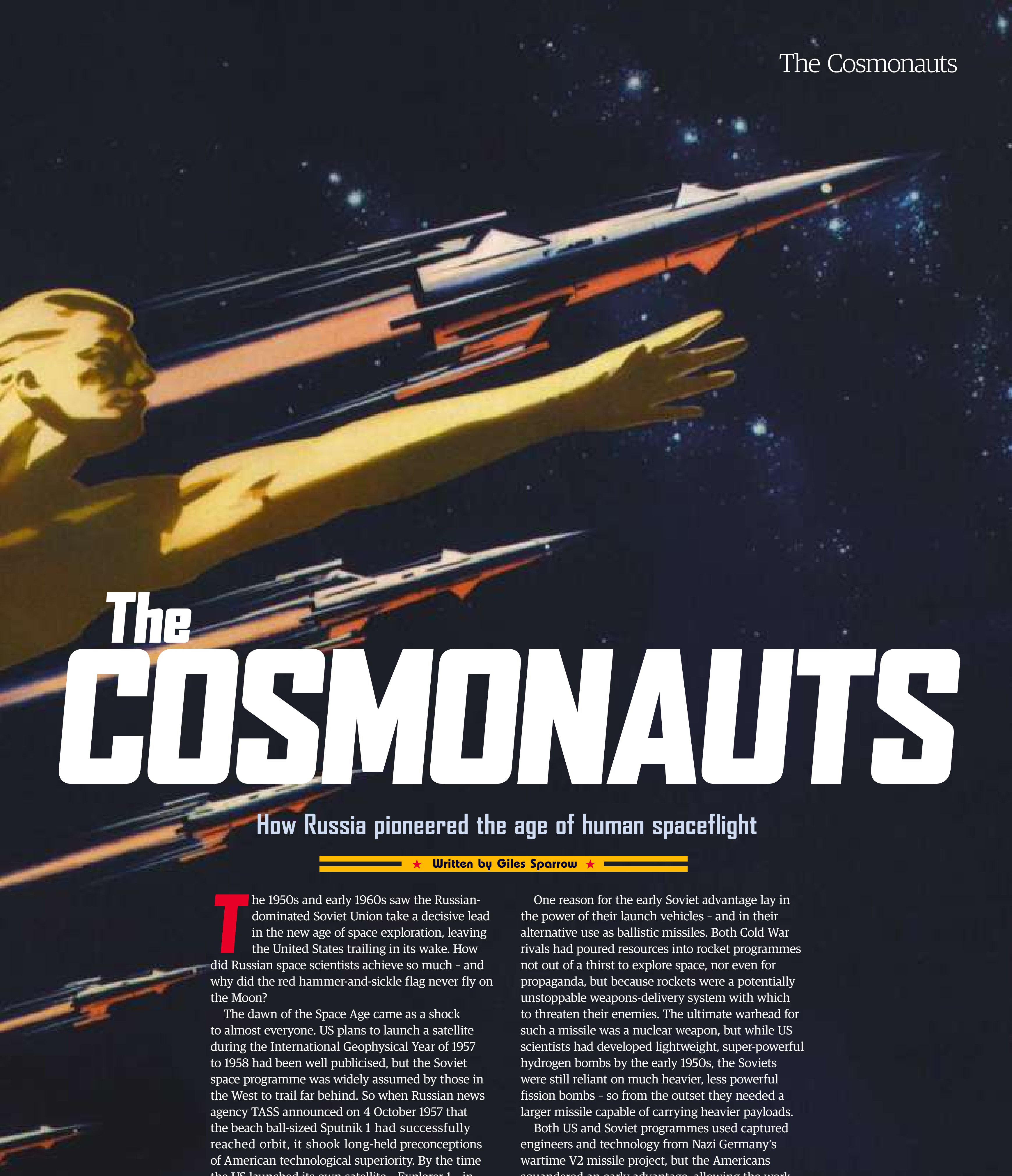
HOW FAR DID VON BRAUN'S NAZI CONNECTION EXTEND?

Wernher von Braun maintained throughout his life that he was not a Nazi, although like many members of the German intellectual elite, he was a member of the Party. He explained in an affidavit to US forces that: "In 1939, I was officially demanded to join the National Socialist Party. At this time I was already Technical Director at the Army Rocket Centre at Peenemünde (Baltic Sea). The technical work carried out there had, in the meantime, attracted more and more attention in higher levels. Thus, my refusal to join the party would have meant that I would have to abandon the work of my life. Therefore, I decided to join. My membership in the Party did not involve any political activity." However, German records show that he in fact joined the party in 1937. Whether von Braun was mistaken or lying in his affidavit is still a matter of debate.

The German V-2 rockets were built using slave labour from the concentration camps of World War II and von Braun was certainly aware of this. He described conditions in the plant where the rockets were built as "repulsive" but claimed never to have seen prisoners beaten. Several concentration camp survivors came forward in later years to counter this claim, but the allegations were never proven. Wernher von Braun did not, however, deny that he was aware of the brutality of the camps and the slave labour regime that built the German rockets, but did state that he felt powerless to do anything about the terrible conditions.

Wernher von Braun with Fritz Todt, a German engineer notorious for his use of forced labour programmes

Wernher von Braun (in non-military attire) with Nazi officers in 1941



The COSMONAUTS

How Russia pioneered the age of human spaceflight

★ **Written by Giles Sparrow** ★

The 1950s and early 1960s saw the Russian-dominated Soviet Union take a decisive lead in the new age of space exploration, leaving the United States trailing in its wake. How did Russian space scientists achieve so much – and why did the red hammer-and-sickle flag never fly on the Moon?

The dawn of the Space Age came as a shock to almost everyone. US plans to launch a satellite during the International Geophysical Year of 1957 to 1958 had been well publicised, but the Soviet space programme was widely assumed by those in the West to trail far behind. So when Russian news agency TASS announced on 4 October 1957 that the beach ball-sized Sputnik 1 had successfully reached orbit, it shook long-held preconceptions of American technological superiority. By the time the US launched its own satellite – Explorer 1 – in January 1958, the Soviets had also launched Sputnik 2, carrying a doomed passenger in the form of a mongrel dog, Laika.

One reason for the early Soviet advantage lay in the power of their launch vehicles – and in their alternative use as ballistic missiles. Both Cold War rivals had poured resources into rocket programmes not out of a thirst to explore space, nor even for propaganda, but because rockets were a potentially unstoppable weapons-delivery system with which to threaten their enemies. The ultimate warhead for such a missile was a nuclear weapon, but while US scientists had developed lightweight, super-powerful hydrogen bombs by the early 1950s, the Soviets were still reliant on much heavier, less powerful fission bombs – so from the outset they needed a larger missile capable of carrying heavier payloads.

Both US and Soviet programmes used captured engineers and technology from Nazi Germany's wartime V2 missile project, but the Americans squandered an early advantage, allowing the work of the core German 'Rocket Team' (now on the payroll of the US Army and led by the controversial Wernher von Braun) to become bogged down in home-grown genius to lead their effort, in the form of Sergei Korolev, a brilliant and charismatic engineer who had helped pioneer Soviet rocketry in the 1930s.

Korolev was obsessed with using rockets for spaceflight, and as head of the OKB-1 engineering and design bureau, played a skilful political game to convince Soviet premier Nikita Khrushchev that a satellite would be a propaganda coup. But after his first success, he found himself under huge pressure to deliver more space 'spectaculars'. Sputnik 2 was an early response (although it's now clear that the Soviets lied about just how long Laika survived in space), and further satellites and moon probes continued to push the limits of space technology - but the next landmark achievement was clearly to put a human in space.

Korolev's team had begun designing a manned space capsule as early as 1955, but even with a suitable launch vehicle, the project was a formidable challenge. Launching a cosmonaut and bringing them safely back to Earth required development of a spacecraft capable of supporting a human being through the stresses of launch, protecting them for long periods in the vacuum of space, and shielding them from the fiery re-entry into Earth's atmosphere. The final design, known as Vostok, consisted of a spherical descent module housing the cosmonaut, and a conical instrument module based on the Sputnik satellites.

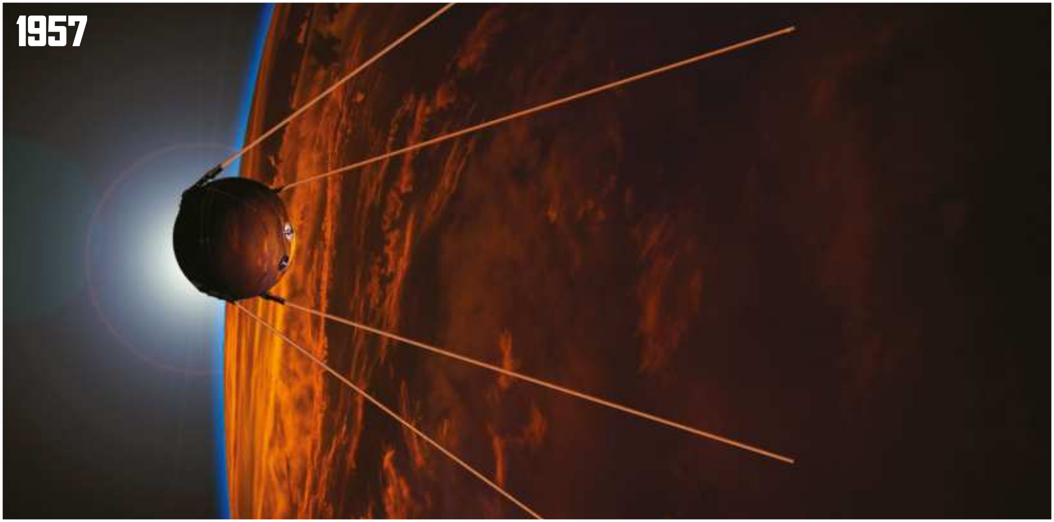
Just as important as the spacecraft were the cosmonauts who would travel in it. An initial group of 20 candidates were selected from among military jet pilots, who volunteered for an unspecified test programme in 1959. Training was overseen by celebrated Soviet aviator General Nikolai Kamanin, and included a huge range of endurance tests for gravity and space sickness, varying oxygen levels, extremes of temperature and isolated, confined conditions. The candidates also attended lectures on spaceflight, although these mainly focussed on biomedical issues - despite the qualifications of the pilots, the Vostok missions were to be controlled entirely from the ground.

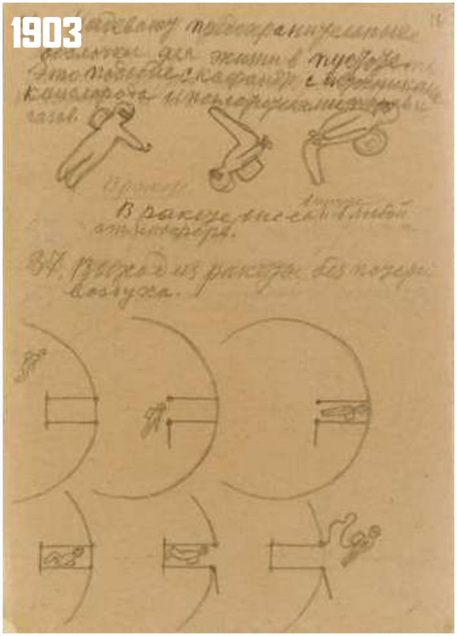
By June 1960, a core group of six cosmonauts were moved to the specially built Star City complex outside Moscow for more intensive training, including spacecraft simulations. Unmanned test flights also began, including some in which dogs were safely returned to Earth. Despite some later rumours, the Soviets were cautious about risking their cosmonauts' lives, and arguments continued until late March 1961 about the decision to launch. Once the go-ahead was given, Korolev and Kamanin's choice of pilot for Vostok 1 came down to two names - Gherman Titov and Yuri Gagarin.

Vostok 1 launched into space on 12 April 1961, orbiting Earth once in 108 minutes and writing Yuri Gagarin's name into the history books. Once again, the US was left behind - delays in the development of boosters suitable for launching large spacecraft meant that their initial response, in early May, was to launch the Mercury Spacecraft Freedom 7 on a sub-orbital 'hop', piloted by astronaut Alan Shepard.

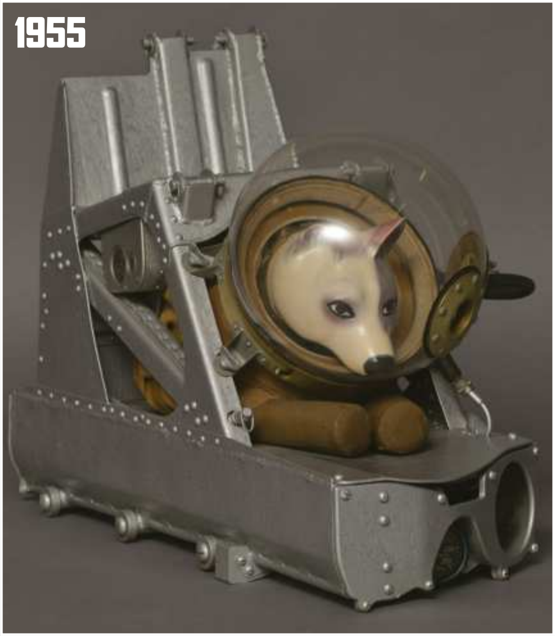
Korolev's team found themselves under increasing pressure to deliver further spectaculars. Titov finally flew aboard Vostok 2 for a whole day in August 1961,

SPACE RACE TIMELINE





87. Выход из ракеты без потери воздуха.



USSR

1903
Russian schoolteacher Konstantin Tsiolkovsky publishes a breakthrough paper explaining the importance of rocket engines for space exploration. In dozens of books and articles, he sets out a vision for the space age, including multi-stage rockets, spacecraft and spacesuits, though he is largely ignored until after the Russian Revolution of 1917.

1950s
Soviet scientists use dogs as test subjects during rocket development - most return to Earth safely, using bizarre devices such as this 'ejector seat'. Laika, the passenger on Sputnik 2, is the only one to be launched with no hope of return, as a re-entry system cannot be developed in time to meet Khrushchev's demands for another quick spectacular.

October 1957
Sputnik 1 is launched using a three-stage rocket based on the Soviet R-7 Semyorka ballistic missile. It enters a highly elliptical orbit ranging from 215 to 939 kilometres (134 to 583 miles) above Earth's surface, sending back a signal that is picked up by radio operators around the world.

1961
Vladimir Chelomei proposes a rival Moon rocket to Korolev's.

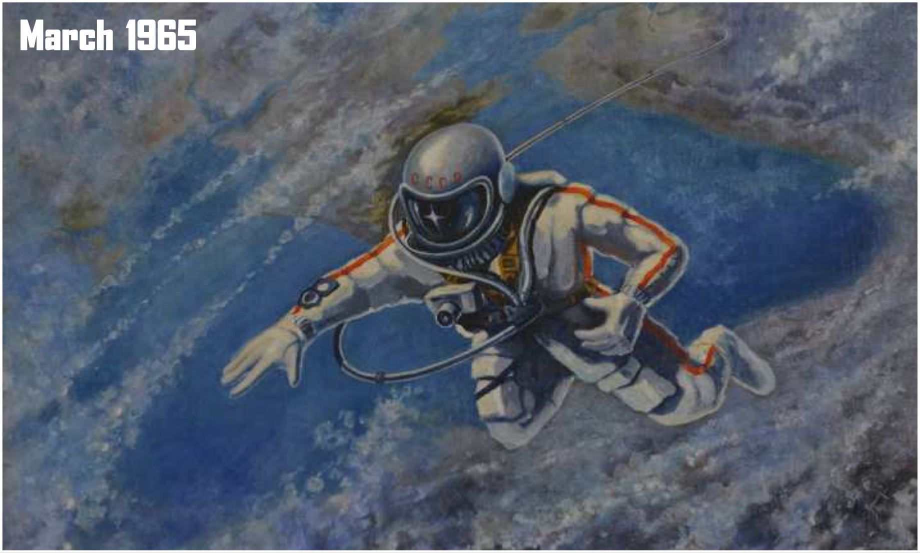
USA

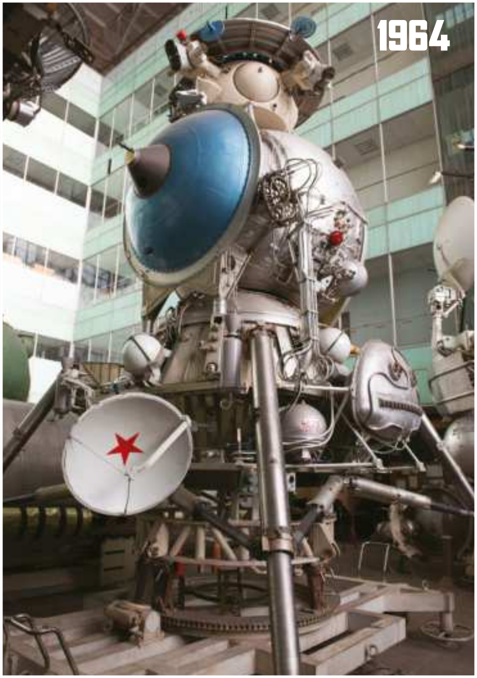
March 1926
US engineer Robert H. Goddard launches the first liquid-fuelled rocket.

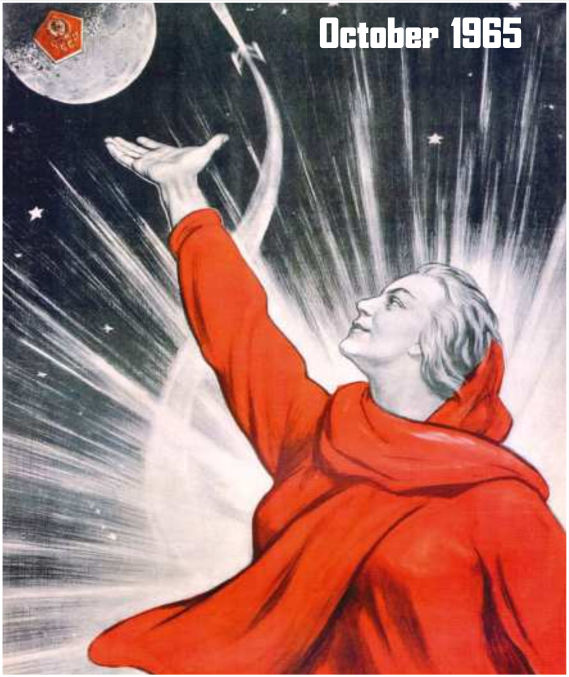
1945
Both US and Soviet forces capture German rocket components and scientists.

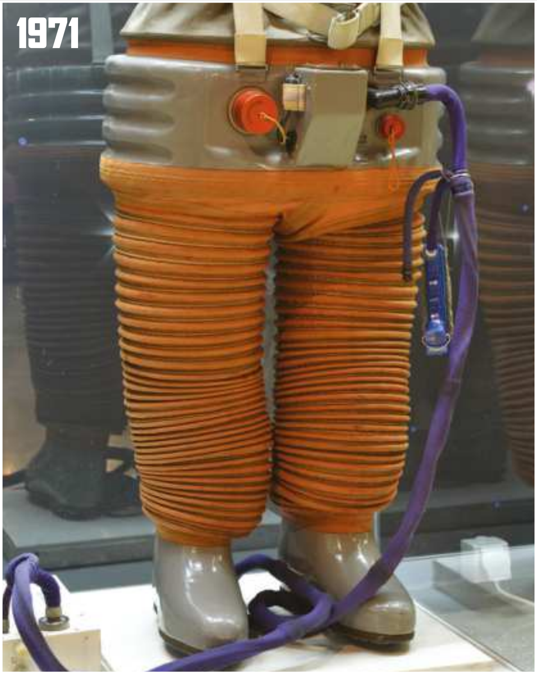
July 1955
The US announces plans to launch a satellite in 1957-8.

January 1958
The US launches the Explorer 1 satellite using Wernher von Braun's Juno rocket.









April 1961

Yuri Gagarin prepares for launch in the cramped confines of his Vostok 1 spacecraft. The ultimate choice of Russia's first cosmonaut may have been swung by Gagarin's peasant background, similar to that of Khrushchev, and deemed particularly fitting for a hero of the Soviet Union.

1964

The Lunniy Korabl lander is the focus of Korolev's lunar mission – planned to launch in combination with a Soyuz-based spacecraft using the huge N1 rocket. Unlike the two-man Apollo lander, the module plans to carry just a single cosmonaut to the Moon's surface.

March 1965

Alexei Leonov's daring spacewalk from Voskhod 2 proves to be the last of the Soviet space spectaculars. It nearly costs Leonov his life, after his spacesuit inflates in the vacuum, leaving him unable to re-enter the capsule. He survives by opening a release valve that lets air escape from the suit.

October 1965

In an attempt to settle the infighting, the Soviet government orders preparation for a manned lunar flyby mission by 1967, using Chelomei's UR-500 launcher and Korolev's Soyuz spacecraft, while work continues on the giant N1 launcher for a later Moon landing.

April 1967

The failure of Soyuz 1 further derails Soviet lunar plans.

1970

The Soviet government begins cancelling manned lunar projects.

1971 onwards

The Soviet space programme begins to focus on long-duration spaceflight and orbiting space stations. Devices such as the Chibis suit are engineered to help cosmonauts remain fit in orbit – the suit is designed to pull blood and bodily fluids away from the torso, where they accumulate in microgravity conditions.

May 1961

President Kennedy announces the goal of putting a man on the Moon.

February 1962

John Glenn, one of the 'Mercury Seven', becomes the first US astronaut to orbit the Earth.

March 1965

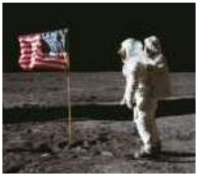
The first manned mission of NASA's Gemini program is launched to low-Earth orbit.

October 1968

NASA launches Apollo 7 to test the Apollo Command/ Service module (CSM) in orbit.

July 1969

The Apollo 11 mission puts American astronauts on the Moon.



READY TO FLY?

The selection criteria for the first cosmonauts were very different from those applied by today's Russian space programme

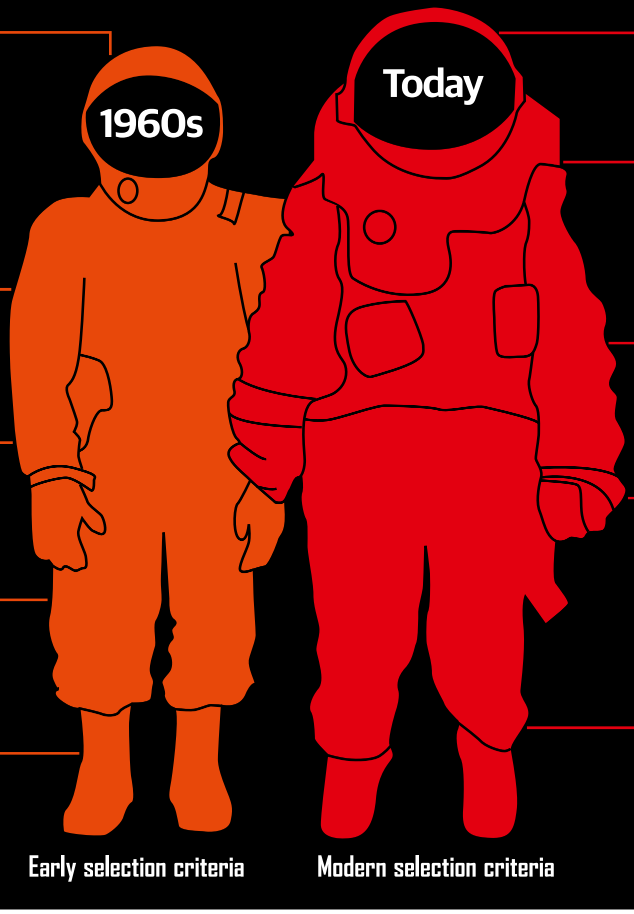
Military pilot
Although early cosmonauts were effectively passengers, jet pilots were considered well suited to cope with the stresses of a spaceflight. Valentina Tereshkova, an experienced parachutist, was given an honorary Air Force rank before her mission.

Age below 30
Cosmonauts needed to combine their flight experience with relative youth – no one could anticipate the physical effects of spaceflight.

Good health
Prior to selection, candidates were screened for chronic health problems. Even minor illness could threaten a pilot with substitution.

Party membership
Given the highly political nature of the Vostok missions, pilots had to be upstanding members of the Soviet Communist Party.

Weight and height
The first cosmonauts could be no more than 1.75m (5.7ft) tall due to the cramped spacecraft, with a maximum weight of 75kg (165lb).



Education
Today's cosmonauts are more likely to be skilled mission specialists educated to degree level or higher.

Health and age
There are no longer direct age restrictions, but candidates (including paying passengers) must display good health and physical fitness.

Height and weight
Today's Soyuz spacecraft can accommodate three cosmonauts with heights of up to 1.9m (6.2ft) and weights of up to 95kg (209lb).

Sponsorship
The Soyuz spacecraft often carries US and European astronauts as well as Russians, as part of partnership agreements with other space agencies. A few wealthy passengers have even paid for a ticket into space.

Training
Modern cosmonauts still undergo intensive training at Star City, working on spacecraft simulators and testing their endurance on parabolic 'weightless' flights.

and a year later Vostoks 3 and 4 flew in space at the same time. In June 1963 another dual flight (Vostoks 5 and 6) saw Valentina Tereshkova become the first woman in space.

By this time, however, the rules of the game were changing – shortly after Shepard's flight in 1961, US President John F Kennedy had given his country a long-term goal of reaching the Moon before the end of the decade. Korolev had similar ambitions, and an advanced spacecraft design called Soyuz that he hoped could do the job.

But political pressure on space scientists to keep delivering short-term 'firsts' was an unwanted distraction, even if it maintained the image of Soviet space superiority. The final Vostok missions were followed by two risky Voskhod flights, using a heavily adapted version of the original one-man spacecraft to set new landmarks. Voskhod 1 took a cramped three-man crew into orbit, while Voskhod 2 carried two men in full spacesuits, allowing cosmonaut Alexei Leonov to open the access hatch and become the first man to walk in space.

Another problem was the fragmented nature of the Soviet space effort – rival designers worked in separate engineering bureaus, often refusing to cooperate with each other, and constantly jostling for attention, political favour and funding. Throughout the early 1960s, priorities were constantly changing, with overlapping or contradictory projects being approved, merged and cancelled.

It was not until 1964 that Korolev was finally given overall control of the Soviet lunar program, which may have streamlined it and helped the USSR to achieve their goals. Development of the enormous N1 Moon rocket was formally approved in early 1965, but problems still continued, with numerous technical delays and obstruction from Korolev's rivals. By this time, Korolev's health had been failing for several years, and in January 1966, he died from complications during routine colon surgery.

His death left the Soviet space programme rudderless – after the problems of the early 1960s it is doubtful that even Korolev could have beaten America to the Moon, but his successors certainly could not. Soviet ambitions to send cosmonauts to the Moon and beyond faded slowly, but perhaps the worst blow came in April 1967, when Vladimir Komarov died during the emergency re-entry of Soyuz 1 – a mission launched under intense political pressure with poor planning and an untested spacecraft. The Soviets had achieved so much, but their luck had finally run out.

Nevertheless, the Soviet space programme rose again. The problems with Soyuz were resolved and it has since become the most successful and reliable manned launch system, allowing cosmonauts of the 1970s and 1980s to carry out increasingly ambitious missions to a series of Salyut and Mir space stations.

Following the fall of the Soviet Union, the rival design bureaus were finally unified in 1992 under a single space agency, named Roscosmos. OKB-1, Korolev's former bureau, today continues as the private company RSC Energia, prime contractor for Russian manned spaceflight. As a result, its legacy lives on on board the International Space Station and in the spacecraft that crew and supply it today.

> "Political pressure on space scientists to keep delivering short-term 'firsts' was an unwanted distraction"

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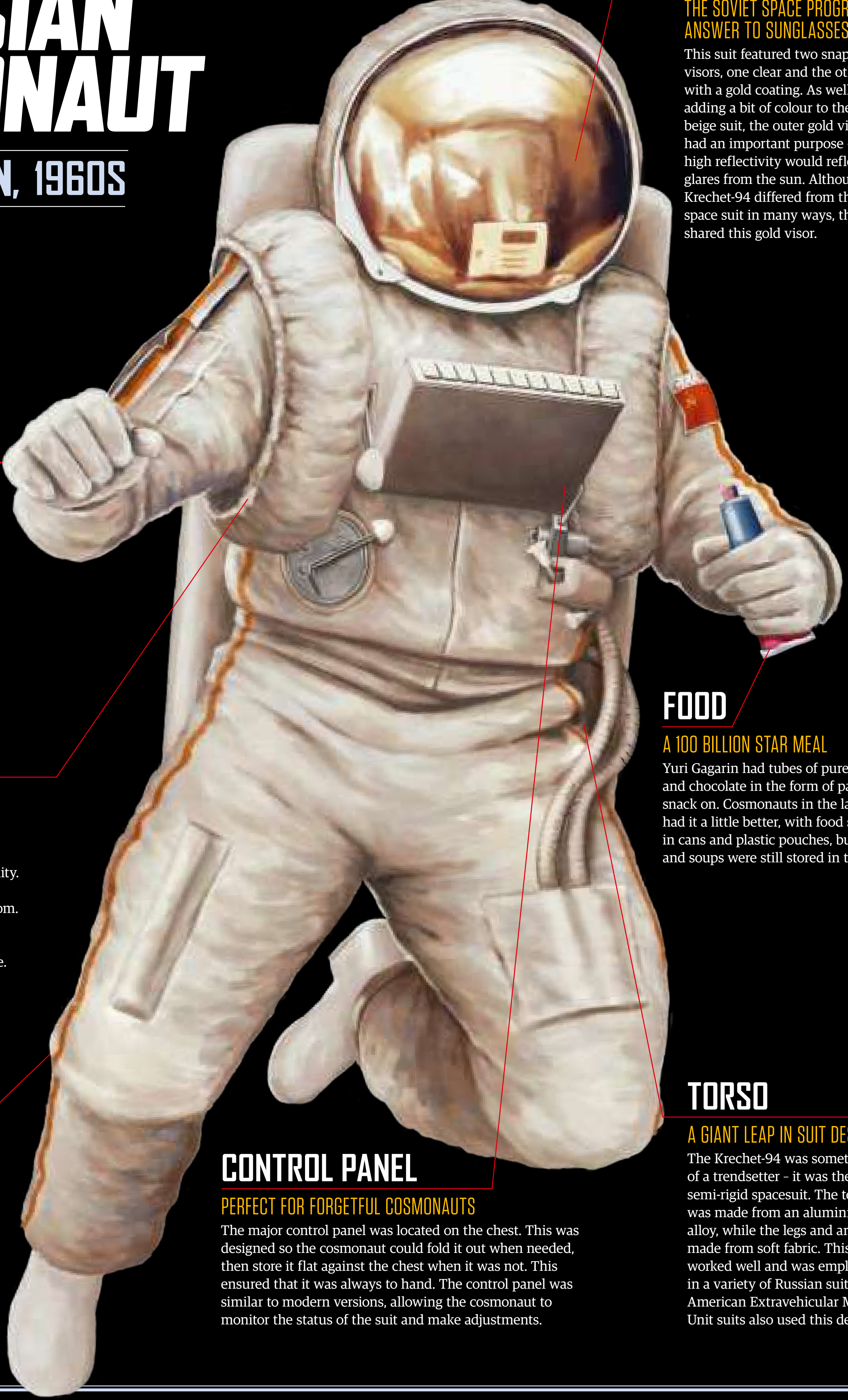
THE ANATOMY OF A RUSSIAN COSMONAUT

SOVIET UNION, 1960S



VISOR

THE SOVIET SPACE PROGRAMME'S ANSWER TO SUNGLASSES

This suit featured two snap-down visors, one clear and the other with a gold coating. As well as adding a bit of colour to the dull beige suit, the outer gold visor had an important purpose - its high reflectivity would reflect glares from the sun. Although the Krechet-94 differed from the Apollo space suit in many ways, they both shared this gold visor.

BACK HATCH

FOR THE ALL-IN-ONE GARMENT

The Krechet-94 was a rear-entry, as opposed to a waist-entry, suit. This meant that the cosmonaut had to enter the suit through a hatch in the back. It was quite common at the time for zippers to be used in space suits, but these would quickly deteriorate and were not reliable. The life-support backpack was also stored in this hatch, and it could be opened with a lever located near the right elbow.

SHOULDER JOINTS

ENOUGH MOBILITY TO MOUNT A FLAG

The Krechet-94's shoulder joints were developed after much testing. The original Krechet had hard shoulder joints, which badly affected the field of vision and mobility. So the Krechet-94 featured soft single-axis shoulder joints, which allowed more freedom. However, mobility was still limited, so the soviet lunar lander was fitted with a finger controller that even a suited pilot could use.

FOOD

A 100 BILLION STAR MEAL

Yuri Gagarin had tubes of pureed meat and chocolate in the form of paste to snack on. Cosmonauts in the late 1960s had it a little better, with food stored in cans and plastic pouches, but drinks and soups were still stored in tubes.

BACK RING

THE LIFE-SAVING HULA HOOP

After many near misses and several disasters, the USSR wanted to make sure that their cosmonauts were prepared for any eventuality, including falling down. This simple metal 'hula hoop' style ring on the back of the suit could actually save a cosmonaut's life. It allowed any solo traveller who fell on their back to roll on their side, and then get up on their feet.

CONTROL PANEL

PERFECT FOR FORGETFUL COSMONAUTS

The major control panel was located on the chest. This was designed so the cosmonaut could fold it out when needed, then store it flat against the chest when it was not. This ensured that it was always to hand. The control panel was similar to modern versions, allowing the cosmonaut to monitor the status of the suit and make adjustments.

TORSO

A GIANT LEAP IN SUIT DESIGN

The Krechet-94 was something of a trendsetter - it was the first semi-rigid spacesuit. The torso was made from an aluminium alloy, while the legs and arms were made from soft fabric. This design worked well and was employed in a variety of Russian suits; the American Extravehicular Mobility Unit suits also used this design.

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Vice President Spiro Agnew and former President Lyndon Johnson view the liftoff of Apollo 11 from the stands located at the Kennedy Space Center VIP viewing site

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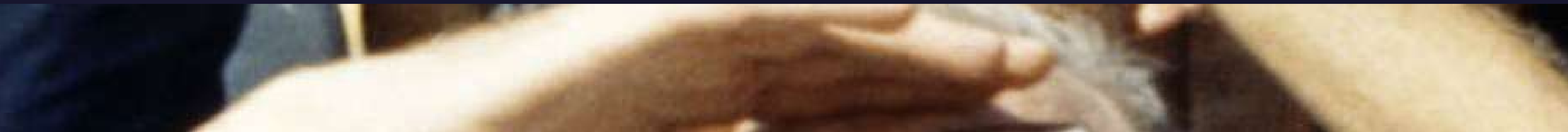
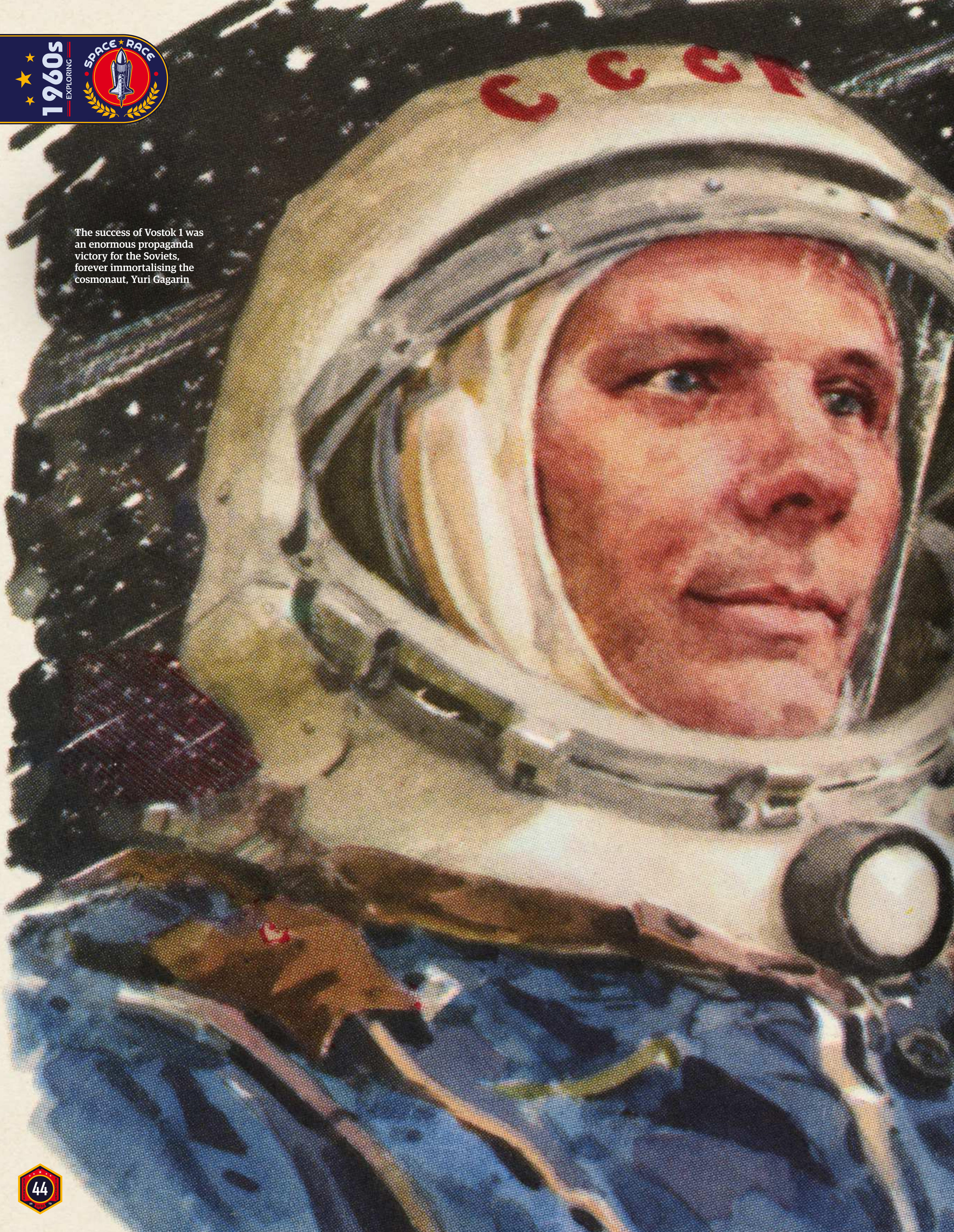


EXPLORING 1960s

SPACE ★ RACE



The success of Vostok 1 was an enormous propaganda victory for the Soviets, forever immortalising the cosmonaut, Yuri Gagarin

12
АПРЕЛЯ
1961

The FIRST MAN in SPACE

After a stellar start to the space race, the Soviet Vostok programme dealt the US a crushing blow

Written by Hareth Al Bustani

By the late-1950s, having kicked off the Space Race by launching Sputnik into Earth's orbit, the USSR went on to develop the first spacecraft to land on the Moon and send the first animal into orbit. With these successive victories over the US space programme, the Soviets gained legitimate ground to claim technological supremacy on the world stage.

However, while dogs and metal were one thing, the Americans were not long behind, and there was still one great defining breakthrough that neither side had yet managed to accomplish - one that would capture imaginations and thrust humans into a new epoch - sending a person into space.

The Soviets began developing systems for a manned orbital satellite in 1958. The project was led by Mikhail Tikhonravov, who had worked on rocket design and space exploration with Sergei Korolev since 1933, and chief conceptual designer Konstantin Feoktistov, a stubborn and brilliant scientist who hoped to one day visit space himself.

In April 1959 the team drew up a secret draft plan of a spacecraft capable of carrying man into space, followed the next month by ballistic calculations with orbital descent options. The army gave them access to firing ranges, military specialists, troops and, crucially, the newly updated R-7A rocket - with an added third stage capable of launching a payload of five tonnes into near-Earth orbit.

While the Americans had successfully developed the Discoverer espionage satellite which would later carry cameras and film, the Soviets still lacked the technology to bring vessels back to Earth - something essential for a manned mission. To speed things along, Premier Khrushchev tasked the Experimental Design Bureau OKB-1 with developing a satellite for reconnaissance and navigation alongside a "sputnik for human flight".

After some heated debates Korolev signed off on a ballistic landing configuration with a spherical descent module, equipped with a thermal shield. An instrument aggregate compartment housing disposable hardware would simply break off before entering the atmosphere.

As the US continued developing its own Atlas missile, capable of carrying over 1.3 tonnes into

YURI GAGARIN

HOW THE WORLD'S FIRST COSMONAUT ROSE FROM AN OBSCURE FARM TO SPACE

Yuri Alekseyevich Gagarin was born in 1934 in the village of Klushino, near Gzhatsk, a region of around 10,000 people in the heart of central Russia. His parents Aleksey and Anna were peasants, members of a collective farm, growing grain and flax.

His early life was a traditional one, growing up in a log hut with a thatched roof, set amidst fields and forests. However, Yuri's world was turned upside down when Nazi Panzer units overran the village in 1941. A Nazi officer took over the Gagarin residence during the last years of occupation.

After the war the Gagarins moved to Gzhatsk, where Aleksey worked as a carpenter, Anna tended the fields and Yuri continued his secondary education – joining the Young Communist League in 1949. He later moved to Lyubertsy, an industrial suburb of Moscow, where he fell in love with volleyball, basketball and, most importantly, aeronautics and space – never missing an airshow at the nearby Tushino Airfield.

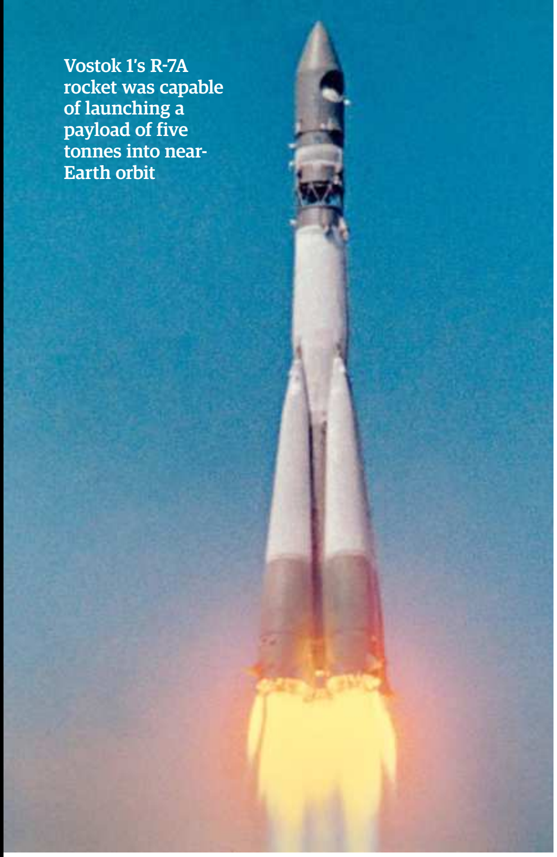
Having graduated from vocational school as a moulder with distinction, he enrolled at an industrial college in Saratov, joining the Saratov Aero Club. After completing his studies he enlisted at a Soviet Air Force training centre, graduating in 1957 with top honours. While there he met the love of his life, Valentina, with whom he would later have two children.

The 27-year-old Yuri Gagarin emerged from the Vostok mission, not just one of 1,200 Gagarins living in Moscow, but a living legend. As Khrushchev would tell him: "You have made yourself immortal, because you are the first to penetrate into space." Named a Hero of the Soviet Union by a smooching Khrushchev, monuments of Yuri were erected across the country and streets were named in his honour.

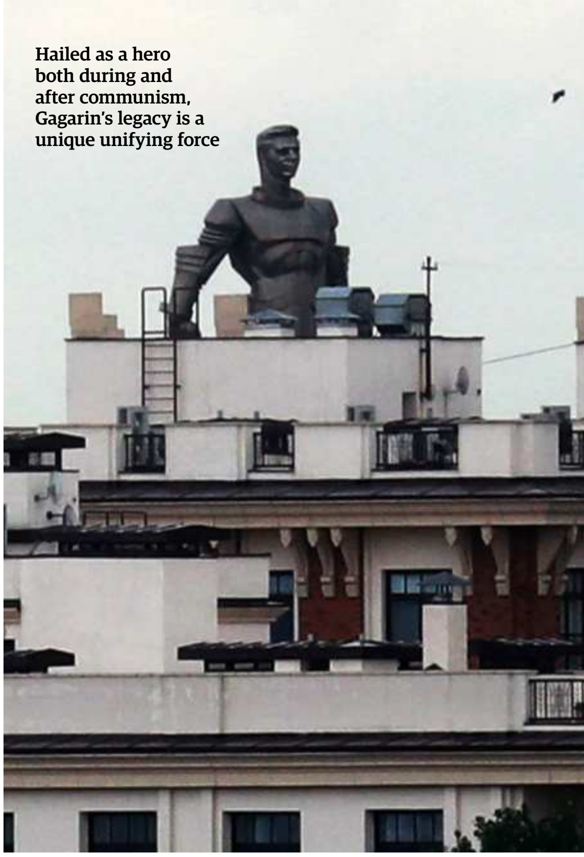
Training future space cadets, he quickly rose up in the Communist party, chairing the Soviet-Cuban Friendship Society, attending the 22nd Congress of the Communist Party and becoming deputy in the Supreme Soviet.

Unfortunately, in 1968, having reached a colonel's rank, Gagarin died test piloting a new aircraft; a devastatingly pedestrian death for one of the USSR's most beloved heroes. Despite his untimely demise, the cosmonaut's reputation outlived that of even the Communist regime. As one writer put it: "When perestroika started and all the heroes of the previous years had been shattered to dust, the only remaining, real, tangible hero was Gagarin; the first man in space, and a good guy whom both the elderly and the young trusted."

Of the 250 candidates brought in for testing, Yuri Gagarin was among the space programme's 'Vanguard Six'



Vostok 1's R-7A rocket was capable of launching a payload of five tonnes into near-Earth orbit



Hailed as a hero both during and after communism, Gagarin's legacy is a unique unifying force

> "After sifting through 3,000 pilots' records, the team initially brought in 250 prospective candidates"

orbit, the pressure was on – failure at this critical juncture would completely undermine the Soviets' cumulative propaganda victories. With the Americans planning to fly the first manned suborbital Mercury mission in 1961, a Soviet document – On a Plan for the Mastery of Cosmic Space – required all testing to be completed by the end of the year.

By now the project had a name: Vostok, or 'East'. Comprising of three vessels – 1K, 2K and 3KA – the first was a reconnaissance satellite, and the third the actual piloted spacecraft. The policy governing the programme required all assemblies, instruments and systems to be tested and certified 'Suitable for 3KA'. The military carried out thorough checks, with chief designers and section heads personally liable for their components, ushering in a new age of quality and consistency for the Soviet space programme.

One early Vostok mission, Korabl-Sputnik 2, carried an assortment of lifeforms into orbit, notably the dogs Belka and Strekla, becoming the first to bring animals back to Earth safely. However, Korolev was concerned that Belka had clearly become distressed during the fourth orbit, and had vomited due to weightlessness. As a result he decided to restrict his manned mission to no more than one orbit, with the ship controlled automatically from the ground and a manual override code handed to the pilot in a sealed envelope – just in case.

Returning to Earth, the braking rocket engine would need to fire its thrust in the opposite direction from the craft's orbital velocity vector. Once the braking burn had been applied the spacecraft would execute a braking turn – the atmosphere slamming the brakes on the remaining energy. The craft would communicate with Earth via a variety of radio links, along with the capacity to broadcast TV from space.

As the project grew increasingly complex, so too did the bureaucracy of OKB-1, as the Council of Chief Designers watched their power dissipate among designers and organisations representing different disciplines. Though the Council of Six remained, Korolev had to bring in 15 new voting members, representing a variety of bodies from the Institute of Aviation Medicine to Air Force Command. Korolev succeeded in establishing himself atop this new hierarchy – named the rocket-space complex – delegating to his deputies, who in turn worked with their relevant chief designers. While the old guard did their best to mitigate risk, young engineers threw caution to the wind, creating a healthy balance of ambition and control.

In 1960, only two of five Korabl-Sputnik launches went into orbit and made it back. With a 'soft landing' system still years away, the only way of ensuring a safe landing for the astronaut was a two-step landing system, which ejected the cosmonaut out of the descent module with a parachute. The following year two further missions carried animals and mannequins into space, safely ejecting the dummy, 'Ivan Ivanovich'.

After sifting through 3,000 pilots' records, the team initially brought in 250 prospective candidates. This number was slowly whittled away by medical examinations, vigorous rotating chair training for weightlessness and ten-day isolation chambers. Of the 12 candidates selected by the Air Force to enter the Cosmonauts Training Center, the six most promising were dubbed the 'Vanguard Six'. Among the six was a young man called Yuri Gagarin, who persevered through the intense training and the Vostok simulator, TDK-1, the first of its kind in the USSR.

Though the Vostok spacecraft was controlled from the ground, a team member secretly informed Gagarin of the override code in advance

СССР
ВОСТОК

The Vostok programme ushered in a new era of efficiency, centred around the Baikonur Cosmodrome

Finally, in March 1961, Korolev recommended the launch of a Vostok spacecraft with a human aboard, approved the next month. Gagarin was selected to pilot the vehicle, with Gherman Titov his backup.

12 April was an auspicious day, marked by a clear, sunny sky over the top-secret launch site in Baikonur, Kazakhstan. Gagarin hugged his comrades and stepped onto the elevator before entering the descent module. When technicians discovered the hatch was not sealed properly, they had to spend an hour resealing it, during which time Gagarin asked for music to be played over the radio.

Leaning back into his foam-padded ejection seat, he yelled, "Off we go," and away Vostok went. Two minutes later the four strap-on boosters ran out of propellant and fell away, and minutes later the rocket core stage followed suit. As the craft soared into space, Gagarin beamed through the radio: "Visibility is excellent! Out the window I see Earth, clouds, I see rivers. It's beautiful."

His spherical cabin featured three portholes, a life-support system, radios and various instrumentation. An attached service module housed batteries, orientation rockets, a retro system and other equipment. Having completed a single orbit and travelling 27,359 kilometres (17,000 miles) per hour, the service module detached and the descent module returned to Earth, with Gagarin ejecting safely. Despite some hiccups along the way, such as a brief detachment scare, the Soviets had done it.

After landing, Gagarin, clad in an orange suit with a white helmet, encountered a farmer and his daughter. "When they saw me in my spacesuit, and the parachute dragging alongside as I walked, they started to back away in fear. I told them, 'Don't be afraid. I am a Soviet like you, who has descended from space, and I must find a telephone to call Moscow!'"

The psychological impact on both the US and USSR was profound – the Soviets emerged the masters of space and technology, and with the US 25 days away from suborbital flight, they would have to set themselves a profoundly ambitious task to return from a defeat of this magnitude.

REACTIONS TO VOSTOK

THE VOSTOK SUCCESS ELICITED POWERFUL REACTIONS OF JOY AND FEAR ACROSS THE WORLD

Thousands paraded across Moscow, chanting 'cosmonaut' to rousing music blasted from loudspeakers. The celebrations continued across the country, as Khrushchev gloated to Gagarin: "Let the capitalist countries try to catch up with our country, which has blazed a trail into space and which has launched the world's first cosmonaut."

Indian Prime Minister Jawaharlal Nehru congratulated the USSR on "a great human victory of man over the forces of nature". Indonesia, meanwhile, said it marked "an entirely new era in human life", hoping it would "have only a beneficial influence on mankind".

Yomiuri newspaper in Tokyo noted that "real competition" was "just beginning", but encouraged the US and USSR to "use their new knowledge and techniques for the good of mankind".

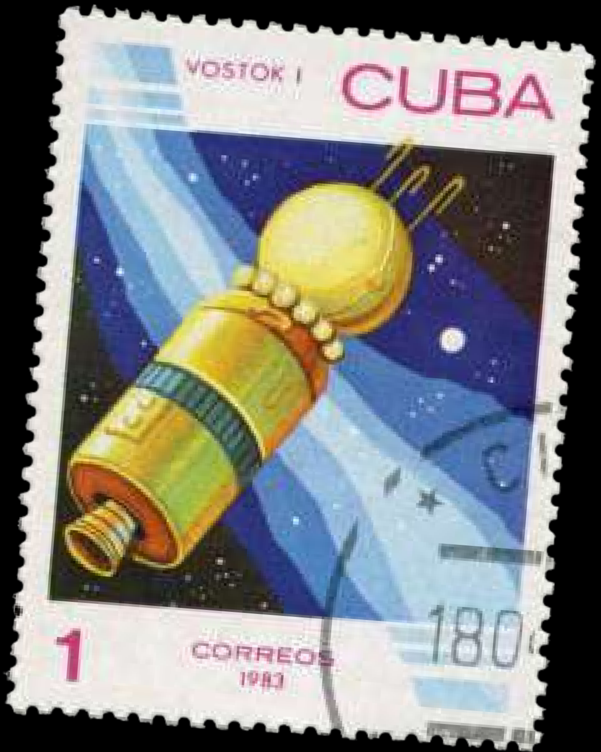
Despite the humiliating blow, President Kennedy extended the Soviet scientists and engineers a cordial congratulations: "It is my sincere desire that in the continuing quest for knowledge of outer space, our nations can work together to obtain the greatest benefit to mankind."

While Wernher von Braun celebrated the "remarkable" achievement, the 'father' of the hydrogen bomb, Edward Teller, said the US' failure to put a man in space first was the result of "years of unimaginative, materialistic thinking".

The German daily, *Die Welt*, said the USSR was now reaping "the benefits of its purposeful efforts", adding: "It could have been avoided. For weeks the Americans had at their disposal the technical know-how required to send a man into space and get him back."

Meanwhile, the director of the School of Physical Sciences at the Australian National University dismissed the mission as "just a stunt", compared to previous accomplishments.

The Vostok mission captured the imagination of the world, a potent symbol of socialism's success



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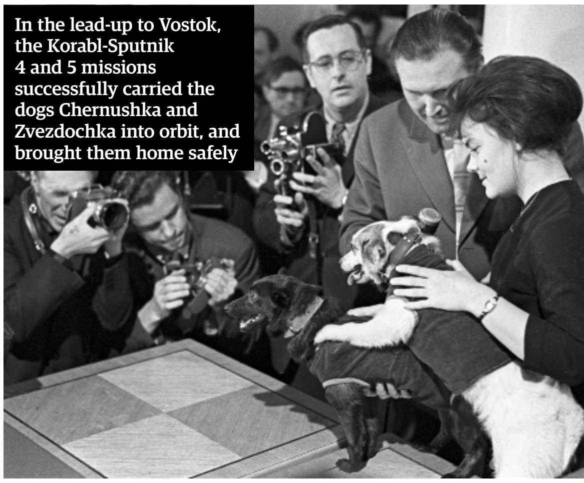
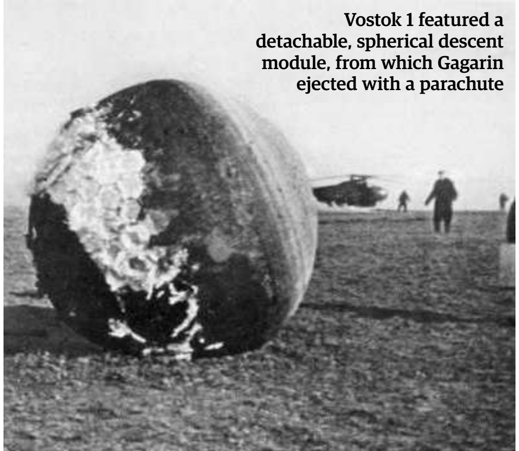
Vostok's success was a source of pride for Soviet citizens, who considered it a victory of socialism over capitalism



In the lead-up to Vostok, the Korabl-Sputnik 4 and 5 missions successfully carried the dogs Chernushka and Zvezdochka into orbit, and brought them home safely



Vostok 1 featured a detachable, spherical descent module, from which Gagarin ejected with a parachute

Khrushchev celebrates alongside Gagarin, right, and Gherman Titov, the backup pilot for Vostok 1, who went on to become the second man in orbit

WELCOME to STAR CITY

Take a tour of the Soviet Union's secret city for cosmonauts in training

Written by Katharine Marsh

It was the USSR's worst kept-secret. Removed from maps, despite the fact that it lay just outside Moscow, Closed Military Townlet Number 1 technically didn't exist – until you came across the large concrete walls crowned with barbed wire. Built in the 1960s, this was where the Soviet cosmonaut training took place, although it's still used today by Russia, the European Space Agency and NASA. But the town had another name, one which the American press much preferred: Zvyozdny Gorodok, or Star City.

COSMONAUT HOUSE OF STAR CITY

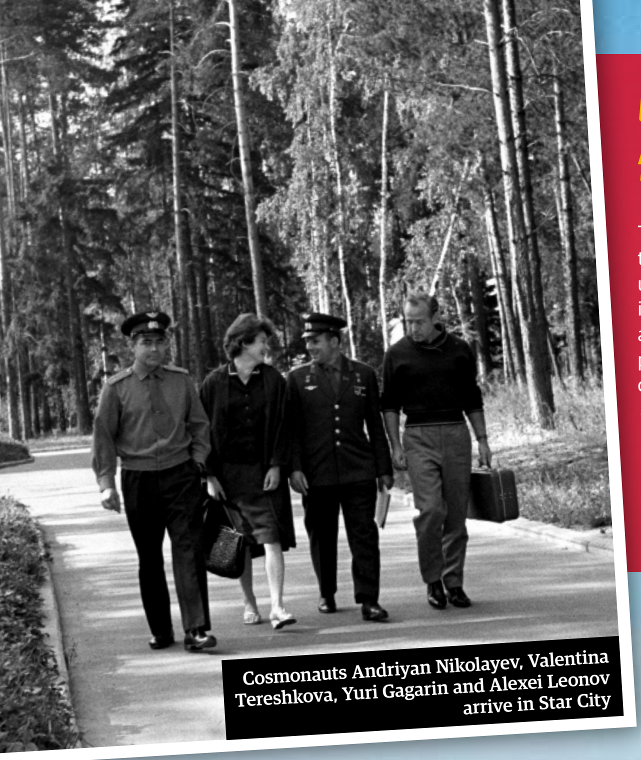
Effectively a community centre, Cosmonaut House is home to the Star City Manned Cosmonautics Museum and a library where the wives of cosmonauts are known for doing book swaps. Constructed with the help of Yuri Gagarin, it also contains a theatre and an indoor flea market.

CHURCH

Star City was without a church for many years, but about ten or so years ago one was built. The Transfiguration Church is built in a typical Russian Orthodox style with dark-blue domes that contrast with the main wooden structure.

NASA'S COTTAGES

Since the thawing of Cold War relations between Russia and the United States, NASA has had an increased presence in Star City. One result of this are the three white American-style cottages that house NASA's astronauts when they are training in Russia's not-so-secret facilities.



Cosmonauts Andriyan Nikolayev, Valentina Tereshkova, Yuri Gagarin and Alexei Leonov arrive in Star City

GAGARIN RESEARCH AND TEST COSMONAUT TRAINING CENTER

The home of Russian cosmonaut training, the Gagarin Center houses full-size mock-ups of all major spacecraft developed in the USSR, such as Soyuz and the ISS, as well as a hydro laboratory, or water pool, that holds a volume of 5,000 cubic metres, thus making it capable of accommodating a 20-ton space station module. The Gagarin Center also has aircraft for imitating weightlessness, a planetarium that can project as many as 9,000 stars and two centrifuges designed to imitate g-force.

FENCED IN

The entire town is enclosed by a tall fence that is topped with barbed wire. As this is still a centre for training astronauts from around the world, security is tight with a checkpoint serving as an entrance and exit.

LIVING QUARTERS

Around 8,000 people live in Star City permanently, including past cosmonauts like Valentina Tereshkova, but this area is off-limits for visitors. For those who have made Star City their home, there's a school, local shops, salon and even a cinema.

YURI GAGARIN'S STATUE

Yuri Gagarin, the first man in space, died young – but many cosmonauts and astronauts still pay tribute to him by laying wreaths at the feet of his statue.

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UNITED STATES
UNITED

Mercury-Redstone 3 is launched with its pilot Alan Shepard, on a suborbital mission to place the first American in space

ALAN SHEPARD The FIRST AMERICAN in SPACE

The Mercury 7 astronaut who made history, paving the way for the US' Space Race success

★ Written by Baljeet Panesar ★

The launch of Sputnik 1 by the Soviet Union on 4 October 1957 came as a huge surprise to America – a worrying indication that the Soviet Union had exceeded the technological capabilities of the US. Then, on 12 September 1959, the Soviets launched Luna 2 – the first spacecraft to land on the Moon, heralding another step forward in the Soviet's space programme. In response to the Luna programme, the US established the Ranger program in 1959. However, the first successful Ranger craft, Ranger 7, would not impact the Moon until some five years later.

Given the threat posed by the Soviets, in 1959 the newly formed NASA invited 110 test flight pilots to volunteer for the US' first manned spaceflight programme, called Project Mercury. The Mercury program had been officially approved on 7 October 1958, and its aim was to successfully place a man into Earth orbit and return him safety – preferably before the Soviets. From a shortlist of 32 candidates, NASA administrator T. Keith Glennan announced the first seven – the Mercury 7, as they were known – on 9 April 1959 after a two-month selection process. They were Alan B. Shepard, John H. Glenn, Virgil "Gus' I. Grissom, Donald 'Deke' K. Slayton, Malcolm 'Scott' S. Carpenter, Walter "Wally" M. Schirra and L. Gordon Cooper. From these seven, it would be Shepard who would be selected to pilot the US' inaugural flight into space.

The Mercury program consisted of six manned flights between 1961 and 1963 – two suborbital missions and four that orbited the Earth. The total flight time for these manned missions was 53 hours, 55 minutes and 27 seconds, but the programme also included some 20 developmental flights. The Mercury program was successfully completed on 16 May 1961 after Gordon Cooper completed a 22-orbit flight in his spacecraft Faith 7. Over the five years of Project Mercury NASA proved that they could place a man in orbit, that he could survive in space and that he and the spacecraft were able to return safely back to Earth.

But before NASA launched men into space, the Mercury spacecraft were tested by launching

> "The Mercury program's aim was to successfully place a man into Earth orbit and return him safety"

On 29 April 1961, Shepard undertakes a flight simulation test in preparation for the history-making flight

A LIFE'S WORK

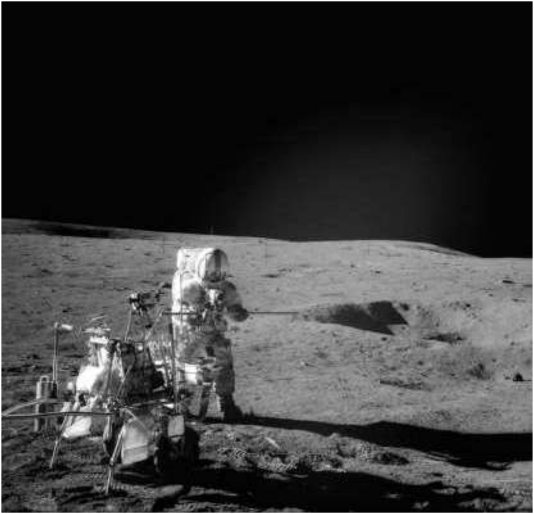
AMERICA'S FIRST MAN IN SPACE WOULD ALSO BECOME THE FIFTH MAN TO WALK ON THE MOON

After graduating from high school, Shepard attended the United States Naval Academy graduating in 1944. He began his naval career on destroyer USS Cogswell in the Pacific Ocean towards the end of World War II. He subsequently completed his flight training at Naval Air Station Corpus Christi, Texas, and Naval Air Station Pensacola, Florida, and received his naval wings in 1947.

In 1950 he attended the United States Test Pilot School in Maryland, where he conducted high-altitude tests for various aircraft and in-flight refuelling systems. He also tested aircraft landings on the first angled carrier deck. He qualified as a test pilot in 1951, and would continue in this role during the 1950s. Shepard would later return as a test pilot and perform test flights with the F3H Demon and F-8 Crusader, as well as acting as project test pilot for the F5D Skylancer. Eventually Shepard became an instructor in the Test Pilot School, logging more than 8,000 hours of flying time, of which 3,700 hours were in jet aircraft.

Shepard was scheduled to command the first manned Gemini mission, but he was grounded after being diagnosed with Ménière's disease, an inner ear disorder which affects hearing and balance. However, years later he would undergo surgery which would allow him to fly once again.

In January and February 1971 Shepard acted as commander of the Apollo 14 mission, becoming the fifth man to walk on the Moon – the only Mercury astronaut to do so. During this mission Shepard became the first – and only – person to hit a golf ball on another celestial body outside of Earth. This science experiment demonstrated how objects behave in the Moon's lower gravity. Over his two spaceflights Shepard logged a total of 216 hours and 57 minutes in space, of which nine hours and 17 minutes were spent on a lunar extravehicular activity.


During the 33 hours that Shepard (pictured) and Mitchell were on the Moon, they completed two moonwalks totalling over nine hours

On 5 May 1961, Shepard made a 15-minute suborbital flight, securing him the accolade of the first American in space

ANCIENT EARTH ROCK FOUND ON THE MOON

THE 4-BILLION-YEAR-OLD EARTH ROCK THAT WAS BROUGHT BACK TO EARTH

Shepard would later command the Apollo 14 mission, with Stuart A. Rossa as the Command Module pilot and Edgar D. Mitchell as the Lunar Module pilot. The mission was the third to land on the Moon and the eighth manned mission of the Apollo program, landing in the Fra Mauro region. The crew conducted geological and seismic experiments.

On 6 February 1971 the crew collected some 42 kilograms (93 pounds) of Moon rock that was brought back to Earth. Almost 50 years later it was discovered one of these Moon rocks – a nine-kilogram (20-pound) sample formally named 14321 – may have been formed between 4 and 4.1 billion years ago, about 20 kilometres (12.4 miles) beneath the surface of the Earth. The early Solar System was a violent place where Earth was repeatedly hit by asteroids. It's thought that one of these impacts launched the rock towards the Moon, where it partially melted 3.9 billion years ago and was once again buried. At this time the Moon was three-times closer to the Earth than it is today. It's believed another impact some 26 million years ago pushed the sample back on the lunar surface, where it remained undisturbed until Shepard collected it.

As part of an international collaboration with the Center for Lunar Science and Exploration, researchers found a two-gram (0.07 ounce) fragment composed of quartz, feldspar and zircon which were formed in a low temperature, oxygen environment – conditions commonly found on Earth, but not on the Moon. Although it is possible that the rocks could have a lunar origin, this would require specific conditions which have not previously been observed from samples. But it's possible that more bits of Earth have found their way to the Moon.

Pictured here near Cone Crater, rock 14321 was collected by Alan Shepard from the lunar surface

After a post-flight inspection, Shepard emerges from the Freedom 7 spacecraft

U.S.S. LAKE CHAMPLAIN

monkeys. The most famous is Ham the chimpanzee – the first higher primate to test a spacecraft – who was launched aboard the Mercury-Redstone 2 mission in January 1961. Although the mission was (mostly) successful and Ham returned to Earth without injury, problems with the Redstone became apparent. Consequently, NASA and its rocket engineer Wernher von Braun decided to add an additional unmanned flight in March 1961. This was a precautionary measure after a failed launch attempt in November 1960 where the rocket rose only ten centimetres (four inches) off the launch pad. This additional flight was successful, but postponed Shepard's flight to May. The additional months ensured that the Redstone was safe for Shepard, but it provided an opportunity to the Soviets, allowing them to get even further ahead in the Space Race against the US.

After a rigorous training schedule, including a series of launch simulations, the first performed on 18 April 1961, Shepard was launched from Launch Complex 5 at Cape Canaveral Air Force Station in the Freedom 7 spacecraft aboard the 25-metre (83-foot) Mercury-Redstone 3 launch vehicle on 5 May 1961 at 09:34 EST (14:34 UTC). The formal countdown for the start of the mission started the day before,

Shepard receives his Distinguished Service Medal from President Kennedy on 8 May 1961

The view from Freedom 7: Shepard reported seeing Florida's west coast and Lake Okeechobee, and the Gulf of Mexico

> "An estimated 45 million people watched Shepard's flight in the US"

and by the time Shepard was launched he had spent more than four hours in Freedom 7, famously encouraging NASA technicians to "fix your little problem and light this candle". These delays were a result of weather conditions that prevented filming of the launch, and last-minute repairs which had to be made to the spacecraft.

The cramped Freedom 7 spacecraft only had enough room for one man, and was 3.51 metres (11.5 feet) high and 1.89 metres (6.2 feet) in diameter - smaller than the Vostok 1 spacecraft, which had a height of 4.4 metres (14.4 feet). The Redstone rockets were initially used as missiles by the US Army and were modified to allow for the launch of a manned Mercury capsule.

23 days earlier, Soviet cosmonaut Yuri Gagarin became the first person in space - the Soviet Union's second major victory over its American rivals - reaching a maximum altitude of 327 kilometres (203 miles). Shepard's original mission was scheduled for 2 May 1961, but the historic flight was delayed due to weather conditions. Unlike Gagarin, who completed a 108-minute flight that also orbited the Earth, Shepard's historic flight lasted 15 minutes and 28 seconds but did not orbit the Earth, a milestone that was achieved by John Glenn who completed three orbits of the Earth on 20 February 1962.

Freedom 7 was programmed to complete a ballistic trajectory, carrying Shepard to an altitude of 187 kilometres (116.5 miles) and reaching a maximum speed of 8,262 kilometres (5,134 miles) per hour. Using Freedom 7's periscope - the spacecraft did not have a window - and having become the first American to observe the Earth, Shepard exclaimed: "What a beautiful view!" During the flight Shepard was capable of manoeuvring Freedom 7 using hand controls to activate the spacecraft's thrusters, whereas Gagarin's flight was entirely automatic, but Gagarin had travelled at a speed of over 27,000 kilometres (17,000 miles) per hour. Having experienced forces as high as 11gs (11-times the force of gravity) during re-entry, the spacecraft's parachute was deployed, making a successful splashdown in the Atlantic some 488 kilometres (303 miles) from Cape Canaveral.

Gagarin's triumphant flight saw him eject from his spacecraft at an altitude of seven kilometres (23,000 feet) and return to Earth using a parachute, which was not disclosed at the time and remained confidential for years. Shepard and the spacecraft were recovered by helicopter and taken to the USS Lake Champlain aircraft carrier which was awaiting their arrival, and he was greeted with a hero's welcome. After a post-flight medical investigation, doctors reported that Shepard was "disgustingly normal". 20 days after Shepard's success, President John F. Kennedy committed America to landing a man on the Moon by the end of the 1960s, thereby ending the Space Race.

The success of the mission also ensured that the spacecraft and booster were closer to being certified for Earth-orbiting missions. For becoming the second person in space, Shepard received the NASA Distinguished Service Medal from President Kennedy, as well as the Distinguished Flying Cross. Following the success of Shepard's flight he was treated as a national hero, with ticker-tape parades in his honour, once again uniting Americans with a sense of achievement and pride at the US' space efforts. Despite the possibility that the flight may not have been successful, it was broadcast on television and radio with an estimated 45 million people watching Shepard's historic flight in the US alone, allowing the world to watch the technological advances of a superpower. This was important given the criticism NASA had previously faced from the media and the public over the Soviet Union's progress and its initial domination of space. Although Gagarin's name was highly publicised, the history-making flight, as well as any setbacks, were not broadcast, in keeping with the secrecy in the Soviet Union.

Although the US appeared to be behind in the Space Race, Shepard's historic flight helped gain support for its space exploration programme, and allowed the American people to share the excitement, anguish and success of spaceflight with the brave and courageous men who travelled to space. The accomplishments of the Mercury program provided the foundation for the successes of the subsequent Gemini program and Apollo manned missions, and the US' eventual superiority space exploration.

Within 11 minutes of splashdown in the Atlantic Ocean, Shepard and Freedom 7 were flown to their recovery ship

Shepard entering the Freedom 7 spacecraft in his pressure suit and helmet

The Mercury 7 were NASA's first group of astronauts, selected in April 1959

© All images NASA; Edgar D. Mitchell

СССР

The FIRST WOMAN in SPACE

How a girl from a textile factory followed her dreams and reached the stars

Written by Frances White

The humble beginnings of Valentina Tereshkova could never have predicted the ripples she was fated to create across the globe. She was born on 6 March 1937 in the village of Maslennikovo, approximately 270 kilometres (170 miles) from Moscow. Her parents were migrants from Belarus, with her mother working in a textile plant and her father a tractor driver. Sadly, her father was killed during World War II. Tereshkova's education in her youth was minimal; she didn't attend school until she was eight years old, and she left when she turned 16, joining her mother in the textile factory. However, despite having to leave school to make a living, she continued to pursue education through correspondence courses from an industrial school.

Although her life seemed destined to be spent in the same textile factory as her mother, and confined to the same small village, Tereshkova had unusual hobbies and interests, ones that would open up a world of possibilities. One of these was parachuting. She had been interested in parachuting from a young age, and joined the Yaroslavl Air Sports Club. She made her first jump aged just 22. Not just a thrill seeker, she was also an intellectual, fascinated by politics. She joined the local Young Communist League and became secretary in 1961, and later joined the Communist Party of the Soviet Union. Tereshkova was not happy with a life confined to a textile mill… she wanted more. She wanted to fling herself from planes, and then afterwards debate the nation's issues. Though some critics would later claim she was no more than a puppet for the country to tug the strings of, it's clear to see that from an early age Tereshkova was driven to shoot for the stars.

It was the flight of Yuri Gagarin in 1961, the first human to travel into outer space, that would truly transform Tereshkova's life. After having already put the first man into space, Sergei Korolev, the chief Soviet rocket engineer, decided that it was time to do the same again, but this time with a woman. Tereshkova was immediately interested, and volunteered for the Soviet space programme.

> "Tereshkova had been interested in parachuting from a young age"

There were over 400 applicants, and Tereshkova was selected along with four others. Tereshkova benefited hugely from her parachuting experience. At the time she had completed 126 jumps, and cosmonauts were required to parachute from their capsules before they hit the ground upon returning

Tereshkova was not only the first woman to fly in space, but also the first civilian

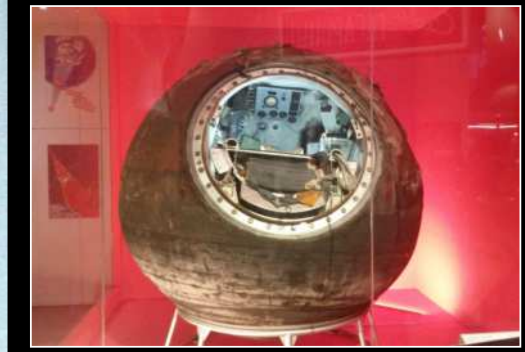
> “She had to be not only a pilot, but also an engineer, a doctor and a navigator, and it required a gruelling training schedule”

to Earth. Applicants were also required to be under 30 years of age, under 70 kilograms in weight and under 170 centimetres (five-and-a-half feet) tall. The woman from Maslennikovo ticked all the boxes.

Tereshkova's world transformed overnight. Along with the three other women, she underwent 18 months of intense training. All these women were burning with desire and ambition to go into space, but none of them were pilots. Whereas in modern spaceflight, where each crew is comprised of specialists, the cosmonauts of these earliest days of space travel were expected to fulfil all roles. Tereshkova had to be not only a pilot, but also an engineer, a doctor and a navigator, and it required a gruelling training schedule. Tereshkova underwent weightless and centrifuge tests, was trained in rocket theory and spacecraft engineering and had pilot training in MiG-15UTI jet fighters, along with parachute jump after parachute jump. To prepare herself for the solitude of space travel, she spent hours alone in a silent chamber. The women underwent examinations to ensure they were prepared for the demands of a flight into outer space.

After months of training, finally Tereshkova was ready to achieve her dream. Originally it was planned that she would launch in Vostok 5, with her

Vostok 6 was the last flight of a Vostok SKA spacecraft



VOSTOK 6

HOW THE CRAFT AND SUIT WERE DESIGNED TO CARRY TERESHKOVA INTO HISTORY

Although spaceflight sounds glamorous now, the conditions that Tereshkova had to endure were anything but. Far from the roomier spacecraft we see today, the Vostok 6 consisted of a spherical cabin covered with ablative material. She was strapped to an ejection seat inside the pressurised cabin, which was only 2.3-metres (7.5-feet) wide. Tereshkova was able to glimpse the Earth through three small portholes. The cabin contained only the essentials, such as radios for communication, a life-support system, instrumentation and an ejection seat. The service module attached to the cabin carried chemical batteries, the retro system, support equipment and orientation rockets. Upon re-entry to Earth, this service module was separated from the main cabin.

To be launched into orbit, the ship was aided by an R-7 booster rocket. This was the world's first intercontinental ballistic missile. Somewhat poetically, it was originally developed to carry nuclear bombs, but eventually ended up carrying a human into outer space. Tereshkova's SK-2 spacesuit was very similar to the one worn by Yuri Gagarin; however, it was modified for a female. Unlike the classic Moon-landing suits it was only designed to be pressurised in the event of the cabin pressure being lost, and to aid in the parachute landing, and was not designed for space walking. Comfort, however, was not factored into the equation at all, making for a cramped and painful flight for the intergalactic adventurer.

The boots on Tereshkova's spacesuit were specially designed for her parachute landing

Tereshkova and Gagarin both became powerful tools for the Soviet Union to use to send a strong message

fellow trainee Valentina Ponomaryova following her in Vostok 6, as the two highest achievers. However, plans changed. It was later decided a male cosmonaut would fly in Vostok 5, and Tereshkova would conduct a solo mission in Vostok 6. Tereshkova had been picked from all the female candidates to undergo the monumental flight, and she was aged just 26 years old.

On the morning of 16 June 1963, Tereshkova prepared herself for the historic flight. She dressed in her spacesuit and, not willing to be outdone by her male counterparts, followed the tradition of urinating on the tyre of the bus that picked her up to transport her to the launch pad. Another first for female cosmonauts. She was sealed inside the spacecraft and waited there during a two-hour-long countdown. Finally the ambitious girl from the textile factory was launched into space. Her call sign was Chaika, or 'Seagull', which she yelled in jubilation as she made history.

Despite her monumental achievement, the flight was not exactly a comfortable one for Tereshkova. She experienced severe nausea along with physical discomfort in the tiny ship. Her sickness was not due to motion, but due to the terrible quality of food she was given. She was also ordered to remain strapped into her seat, but this resulted in cramp in her leg, which she described as 'intolerable', as well as a rash and itch that couldn't be scratched. Despite this she spent three days in space and orbited the Earth 48 times. This single flight amounted to more flight time than all the American astronauts combined. The mission provided valuable data concerning the effects spaceflight had on the female body, and Tereshkova also maintained a flight log. She took photographs of the horizon, which were later used to help identify aerosol layers in the atmosphere. She also manually oriented the spacecraft. While on board, live television was broadcast from the craft, and Tereshkova even spoke with Premier Nikita Khrushchev via a camera. When Vostok 6 was launched, the two vessels came within 4.9 kilometres (three miles) of each other in orbit, and the two cosmonauts exchanged communications via radio.

With over 70 hours logged in space, the mission was an apparent success. However, there were complications that were covered up for almost 40 years that Tereshkova was forbidden to speak of. An error in the ship's navigation software caused the craft to move away from Earth. This sounds minor, but could have ended in tragedy and disaster for Tereshkova. Luckily the skilled cosmonaut recognised the error and reported it. Soviet scientists worked quickly to develop a new landing algorithm. However, upon parachuting out of her craft, Tereshkova realised that, to her horror, she was heading towards a large lake. Due to her sickness and exhaustion she worried she would not have the energy to swim. Luckily she was blown away from the water by a high wind, but did receive a heavy landing as a result, which left her bruised and a little worse for the wear – but thankfully alive.

Aching and exhausted she may have been, but Tereshkova was soon hailed with the title of Hero of the Soviet Union. She also received the Order of Lenin and Gold Star Medal. Tereshkova was, essentially, an overnight legend. Although Tereshkova herself was delighted with her achievements, there are questions over the USSR's true motivations for putting her in space in the first place. Tereshkova was, to them, the perfect candidate. Her father was a war hero, she had a strong proletarian background, came from humble origins and was a diligent student and worker. She was, in no small way, a communist dream made real. Sergei Korolev, principal designer of the Soviet space programme, admitted that although some others were better prepared than Tereshkova for the trip, she was chosen due to her ability to influence crowds, arouse sympathy and be an enticing spokesperson. Tereshkova was very eager to fly again after her world-record-breaking flight, but just like Gagarin before her, she was considered too powerful a propaganda tool to risk. Tereshkova's image was used to emphasise the strength and success of the Soviet space programme. Her face was put on stamps, her image immortalised in monuments.

Like Gagarin, Tereshkova's public image was controlled and dictated. But while he was the military hero, she was the soft, feminine, peaceful

> "She experienced severe nausea along with physical discomfort"

Tereshkova was tested to ensure her body could cope with being sent into space

Tereshkova was selected from over 400 applicants

Tereshkova shortly after her landing, some bruising is visible on her head

WOMEN OF SPACE

TERESHKOVA BLAZED A TRAIL THROUGH SPACE FOR AN ARRAY OF AMBITIOUS AND INCREDIBLE WOMEN TO FOLLOW

Sally Ride

Born in LA, Ride originally pursued a career in professional tennis, but then went on to study science, obtaining a doctorate in physics in 1978. Beating out thousands of applicants, Ride was chosen to be one of six of NASA's first female astronauts that same year. She first worked as a capsule communicator, but aged 32 underwent her first spaceflight as a mission specialist aboard the Challenger. Ride was the first woman to operate the shuttle's robotic arm. Ride also went on to be the first American woman to go into space twice, with a further mission aboard the Challenger. Ride later dedicated her time to encouraging girls to embrace the study of science.

Kalpana Chawla

Born in Karnal, India, Chawla obtained a degree in aeronautical engineering before immigrating to the United States in the 1980s. She continued her studies at the University of Colorado, where she earned a doctorate in 1988. That year she began working for NASA's Ames Research Center. In 1994 she was selected as a candidate to become an astronaut, and her first opportunity to be launched into space came aboard the Columbia in 1997. Chawla made history with this flight as the first Indian-born woman in space. However, her story was tragically cut short when, during the landing of her second shuttle, disaster struck and the ship depressurised, killing all crew on board.

Anousheh Ansari

Ansari is an Iranian-born engineer who immigrated to the United States in 1984. She achieved a master's degree in electrical engineering and computer science at George Mason University. In 1993 she co-founded Telecom Technologies Inc. with her husband and brother-in-law, then went on to also co-found Prodea Systems, a technology and services management company. Ansari made a huge donation to the XPrize foundation and became a spokeswoman for the privatisation of space. In 2006, aged 40, she became the first Muslim woman in space and the first self-funded woman to fly to the International Space Station. She describes herself not as a 'space tourist', but instead a 'spaceflight participant'.

Yi So-yeon

Yi was born and raised in Gwangju, South Korea and earned bachelor's and master's degrees at KAIST, going on to become an engineering physics professor. Yi was chosen as one of two finalists in the Korean Astronaut Program, a South Korean initiative to send the first Korean into space via the Russian space programme. Yi was launched into space in 2008 at an estimated cost of $20 million. Although officially recognised as a spaceflight participant, Yi was involved in many scientific experiments while onboard, such as monitoring the effect spaceflight had on 1,000 fruit flies. Yi experienced a traumatic landing, with the crew subjected to ten-times the normal gravitational forces of Earth.

Helen Sharman

Born in Sheffield, Sharman achieved a bachelor's in science from the University of Sheffield and a PhD from Birkbeck, University of London. She went on to work as a research and development technologist. However, her life changed when she answered a radio advertisement seeking applicants to become the first British astronaut. On 15 November 1989 she was selected live on ITV, beating out 13,000 other applicants. The project was known as Project Juno, a joint Soviet Union-British mission. Sharman received 18 months of intense training for her flight before she was launched into space on 18 May 1991. The Soyuz TM-12 mission lasted eight days, during which Sharman conducted medical and agricultural tests.

A.A.
C.E.САВИЦКАЯ

Svetlana Savitskaya

Savitskaya was born in Moscow in 1948 as the daughter of a famous WWII fighter pilot. She wished to follow in his footsteps, but her air force application was denied due to her age. Instead she took on parachuting, completing 450 jumps before the age of 18. She then began competing for the Soviet National Aerobatics team and achieved a master's in flight engineering. She joined the cosmonaut training programme in 1980 and was launched in 1982 as the second woman in space. Not satisfied with second best, she went on to become the first woman to fly to space twice in 1984, and the first woman to perform a spacewalk. When she arrived at the space station, she was handed an apron and jokingly told to get in the kitchen.

civilian, dressed with immaculate hair, dresses, high heels and make-up. Even her marriage to fellow cosmonaut Andriyan Nikolayev seemed perfectly crafted to fit the Soviet narrative, but Tereshkova denies that this was arranged. Although many believed that Tereshkova's accomplishment was proof of gender equality under communism, it is very difficult to ignore the fact that it took 19 more years for another Soviet woman to be sent into space. Female participation in the Soviet space programme seemed to be yet another way to beat the United States, and to create positive PR.

Indeed, after Tereshkova's flight, several members of the Soviet Air Force immediately attempted to discredit her achievements. Accusations ranged from her being drunk at the launch pad to being insubordinate in orbit, ignoring direct orders and becoming overly emotional. There was particular bad blood around her pointing out the incorrect spacecraft orientation, a concept which is difficult to grapple with, as not pointing it out would have resulted in almost certain death for Tereshkova, who clearly chose to prioritise her own life over the

Tereshkova and Nikolayev were married in 1963

Valery and Tereshkova both became beloved figures in their country after their flights

President Putin congratulated Tereshkova upon her 80th birthday

Tereshkova reportedly ended up vomiting because of the terrible food she was supplied with on her mission

A Russian doll was even made to celebrate Tereshkova's achievement

Tereshkova was subjected to an intense training period to prepare her for spaceflight

embarrassment of her male colleagues. Tereshkova herself denies the claims that she was difficult or psychologically unstable. Cosmonaut chief Nikolai Kamanin agreed with Tereshkova, saying she was never tired, never objected and did all she could to complete the flight programme. Ultimately, Tereshkova's objectors were discredited.

The PR programme behind Tereshkova worked spectacularly well. She became an instant celebrity, travelling the world as a cultural ambassador and spokeswoman. One of the most surprising impacts of her fame was within the United States. The Americans of the Cold War had a very definitive image of what a Soviet woman was – miserable, shabby, wearing terrible clothes, faces without make-up and generally suffering under their government. However, Tereshkova's image directly challenged this. She was a successful female in the world of science but, predictably, the US media focused on her sex appeal, dubbing her 'the Russian blonde in space' – a confusing nickname considering the fact that Tereshkova was a brunette.

However, her success also forced the US to acknowledge that they would also have to tap into their own womens' talents and open up the male-dominated world of science to them, especially if they wished to win the Space Race. Tereshkova caused ripples in the US, with female pilots in full support of her and inspired by her achievements, while some more conservative members of NASA and the US Air Force compared her to the chimps that had been sent to orbit. One NASA spokesperson said the thought of putting women in space made him sick to his stomach. Although Tereshkova challenged American expectations of women, the sexism in the country was a near-insurmountable barrier, and it would take another two decades for an American woman to be sent into space.

> "She was a successful female in the world of science"

Tereshkova herself struggled with the expectations and hero worship she was subjected to. She had always been an ambitious woman, but she never wished to be famous or adored. She certainly didn't want to be hounded by the press. She was subjected to a gruelling schedule where all of her behavior and image was carefully controlled. She could no longer enjoy a private life, and this impacted on her relationship with her husband. Although they had a daughter in 1964 – the first child born to parents who had both been in space – the relationship was strained, and neither of them were happy. However, divorce would mean PR suicide, so the two remained together as a 'happy space family' until 1982.

Although Tereshkova had to deal with the fact she was unlikely to ever be sent into space again, she was not ready to surrender to the life of a Soviet housewife. She became a member of the Supreme Soviet of the Soviet Union and studied at the Zkukovsky Air Force Academy, graduating as a cosmonaut engineer and later earning a doctorate in engineering. She went on to become a prominent member of the Communist Party and represented the nation abroad in numerous international events. Her memberships and accolades included becoming a member of the World Peace Council, achieving the rank of deputy to the Supreme Soviet and being the recipient of numerous prestigious awards.

Tereshkova presented a badge to Neil Armstrong in memory of his visit to the Gagarin Training Center

After the collapse of the Soviet Union Tereshkova lost her political office, but her legendary status did not falter. Today, although somewhat of a forgotten hero in the West, in her homeland she is hailed as a legend, surpassed only by Yuri Gagarin and Alexei Leonov. She was elected to the State Duma where she continues to serve to this day, and carried the Olympic torch in 2008. Upon her 80th birthday she was invited to meet with Vladimir Putin in his residence. It seems age has done little to slow down her thirst for adventure, as she recently said she would like to fly to Mars, even if it was to be a one-way trip.

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VOSTOK 6 MISSION

How the first woman was sent into space

The Soviet Union achieved many firsts in the quest to explore space. They launched the first artificial satellite, Sputnik, in 1957, sent the first animal, Laika the dog, beyond Earth's atmosphere in the same year, and then launched the first human into orbit, Yuri Gagarin, four years later. However, they weren't ready to stop there, and so in 1963 they beat America to yet another space race milestone - sending the first woman into space.

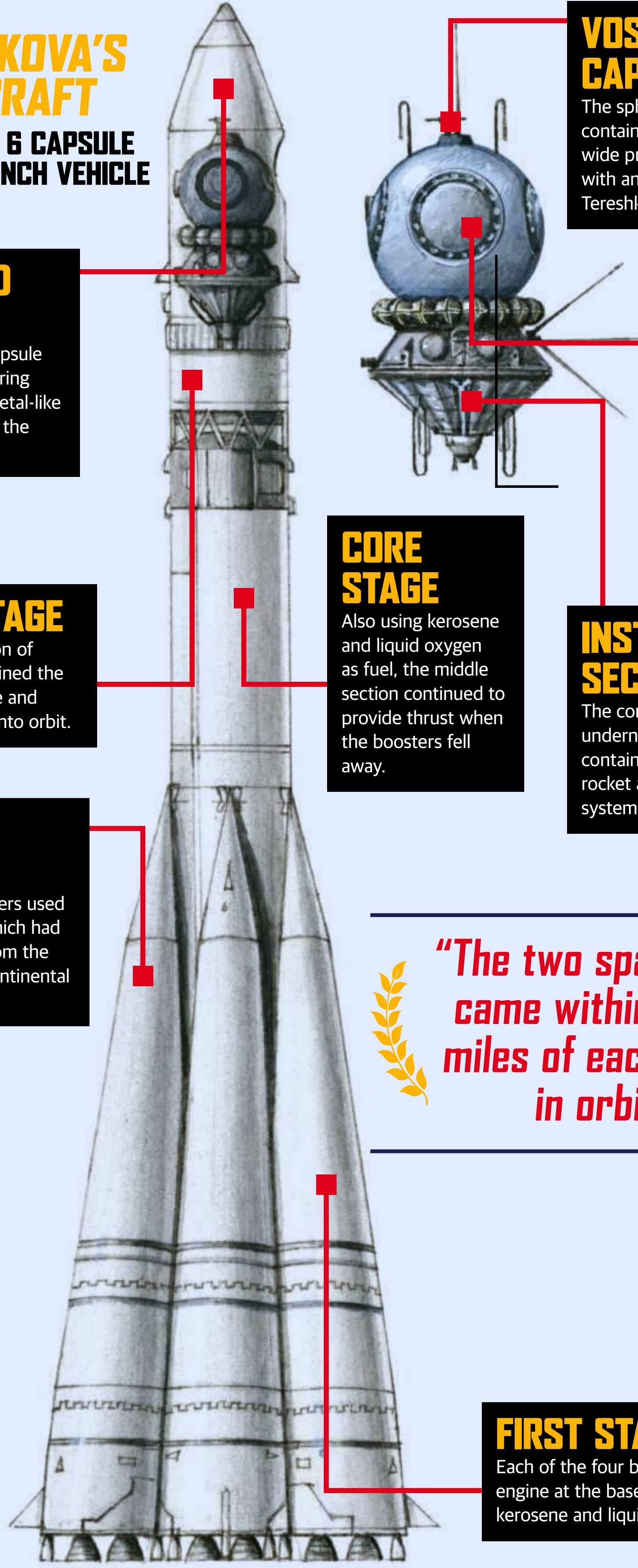
Valentina Tereshkova was a textile factory worker and keen skydiver before starting cosmonaut training in 1962. She was chosen for her excellent parachuting skills, as she would be required to eject from her Vostok 6 spacecraft when returning to Earth and parachute down separately. Just one year later, at the age of 26, she was ready for her mission, uttering the words "Hey, sky! Take off your hat, I'm coming!" just before launch.

However, Tereshkova wasn't actually alone in space, as two days earlier Vostok 5 had launched onto the same orbital path. It was originally intended for both spacecraft to be piloted by women, with Tereshkova at the controls of Vostok 5, but male astronaut Valery Bykovsky ended up in the capsule. The two spacecraft came within five kilometres (three miles) of each other in orbit, and Bykovsky reported that Tereshkova hummed songs to him via radio link before they drifted apart and the connection was lost. After Bykovsky had completed 82 orbits of Earth and Tereshkova had done 48, both cosmonauts successfully returned to Earth on the same day. Tereshkova was almost unconscious when she landed, but by the following day she was well enough to film a re-enactment. She soon became a global celebrity, but it would be 19 years before another woman, Svetlana Savitskaya, would follow in her footsteps.

Much of Vostok 6's heat shield was burnt during re-entry, revealing the insulation layer beneath

TERESHKOVA'S SPACECRAFT

THE VOSTOK 6 CAPSULE AND ITS LAUNCH VEHICLE



PAYLOAD FAIRING

The Vostok 6 capsule was shielded during launch by two petal-like coverings called the payload fairing.

VOSTOK 6 CAPSULE

The spherical capsule contained a 2.3m (7.5ft) wide pressurised cabin, with an ejection seat for Tereshkova to sit in.

AIR SUPPLY

Tanks of compressed nitrogen and oxygen provided breathable air for Tereshkova and propulsion for the spacecraft.

CORE STAGE

Also using kerosene and liquid oxygen as fuel, the middle section continued to provide thrust when the boosters fell away.

FINAL STAGE

The upper section of the rocket contained the Vostok 6 capsule and helped insert it into orbit.

INSTRUMENT SECTION

The conical module underneath the capsule contained the Earth-return rocket and thermal control systems.

ROCKET BOOSTER

The Vostok's boosters used RD-107 engines, which had been developed from the world's first intercontinental ballistic missiles.

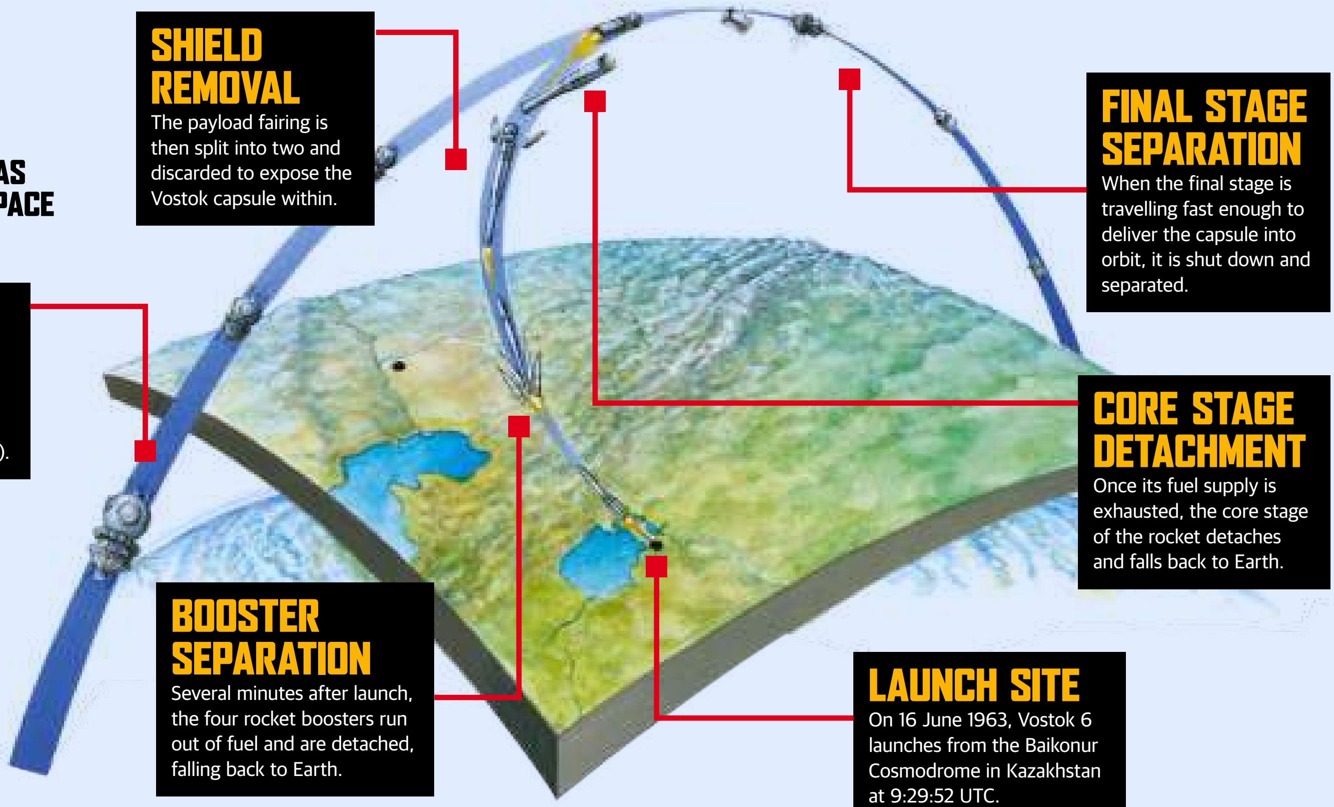
> "The two spacecraft came within three miles of each other in orbit"

FIRST STAGE

Each of the four boosters had a rocket engine at the base, and were fuelled by kerosene and liquid oxygen.

LIFT-OFF

HOW VOSTOK 6 WAS LAUNCHED INTO SPACE



SHIELD REMOVAL

The payload fairing is then split into two and discarded to expose the Vostok capsule within.

IN ORBIT

The Vostok 6 capsule goes on to complete 48 orbits of the Earth, reaching a maximum altitude of 231km (144mi).

FINAL STAGE SEPARATION

When the final stage is travelling fast enough to deliver the capsule into orbit, it is shut down and separated.

CORE STAGE DETACHMENT

Once its fuel supply is exhausted, the core stage of the rocket detaches and falls back to Earth.

BOOSTER SEPARATION

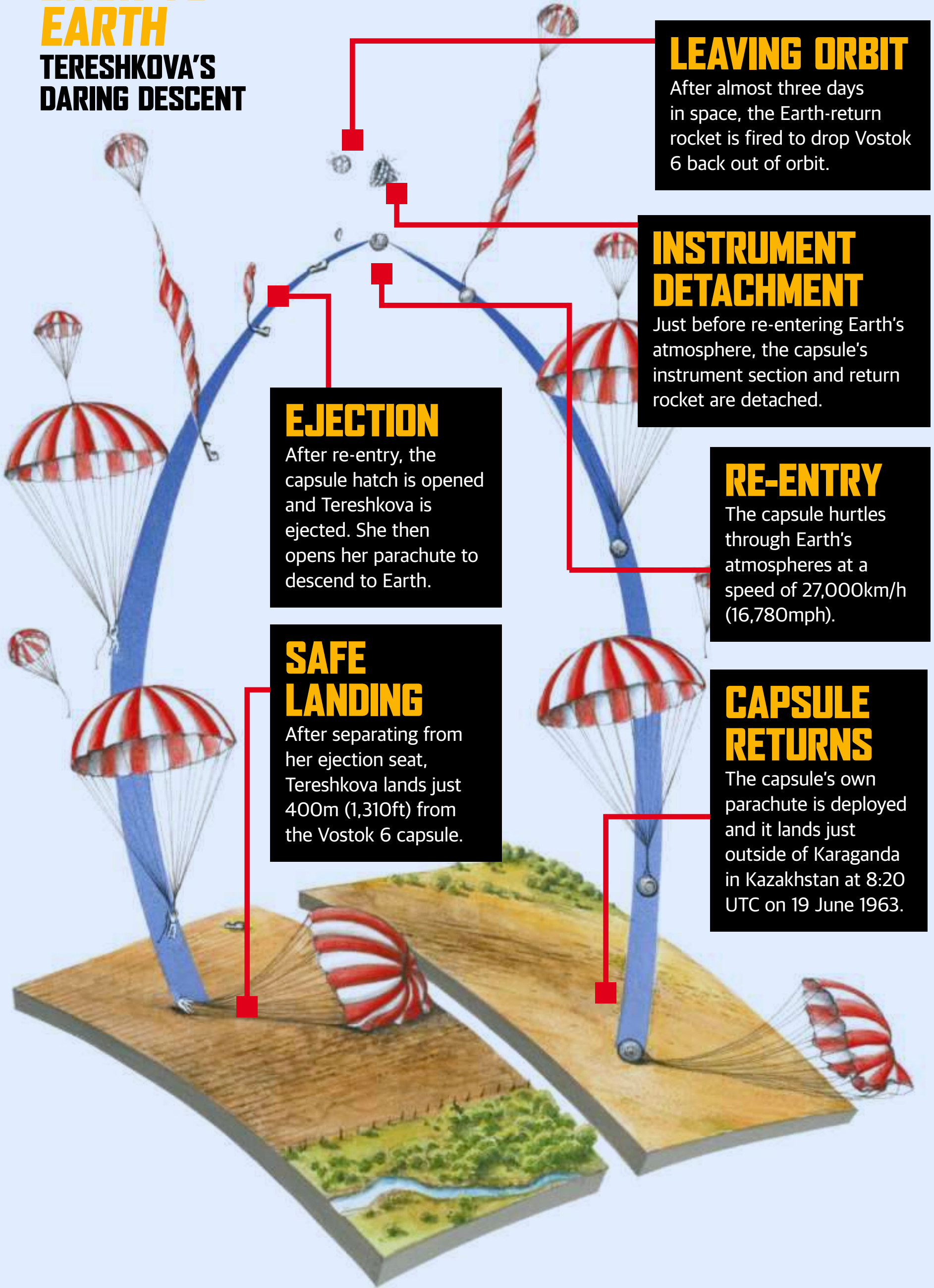
Several minutes after launch, the four rocket boosters run out of fuel and are detached, falling back to Earth.

LAUNCH SITE

On 16 June 1963, Vostok 6 launches from the Baikonur Cosmodrome in Kazakhstan at 9:29:52 UTC.

BACK TO EARTH

TERESHKOVA'S DARING DESCENT



LEAVING ORBIT

After almost three days in space, the Earth-return rocket is fired to drop Vostok 6 back out of orbit.

INSTRUMENT DETACHMENT

Just before re-entering Earth's atmosphere, the capsule's instrument section and return rocket are detached.

EJECTION

After re-entry, the capsule hatch is opened and Tereshkova is ejected. She then opens her parachute to descend to Earth.

RE-ENTRY

The capsule hurtles through Earth's atmospheres at a speed of 27,000km/h (16,780mph).

SAFE LANDING

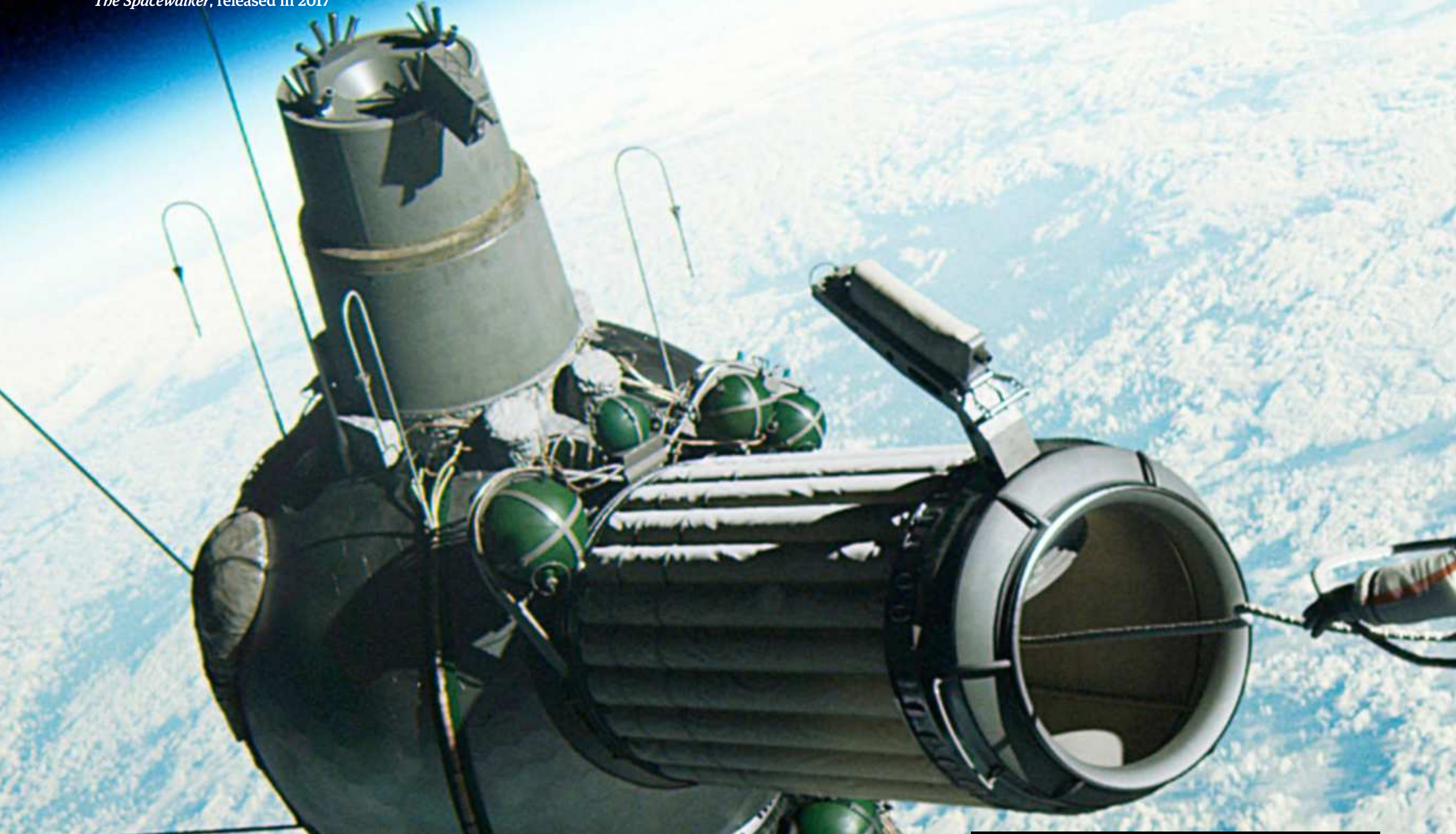
After separating from her ejection seat, Tereshkova lands just 400m (1,310ft) from the Vostok 6 capsule.

CAPSULE RETURNS

The capsule's own parachute is deployed and it lands just outside of Karaganda in Kazakhstan at 8:20 UTC on 19 June 1963.

Tereshkova's call sign for the mission was 'Chaika', Russian for 'seagull'. She had one embroidered on her spacesuit

© Thinkstock; Alamy



Alexei Leonov's extravehicular activity (EVA) as depicted in award-winning Russian film *The Spacewalker*, released in 2017

ALEXEI LEONOV

THE FIRST MAN TO WALK IN SPACE

Today spacewalks are an almost-routine part of space exploration, but the very first spacewalk by Alexei Leonov was anything but straightforward.

Born in the Altai region of Siberia on 30 May 1934, he graduated from a selection of air force academies with honours and was quickly picked to be one of the first 20 people for the Soviet space programme. Leonov had actually expected to become a professional artist, but his life took a very different turn as he became a key player in the Space Race.

In 1965 the Soviet Union was well ahead of the US in the race to land humans on the Moon: they had already launched the first satellite, animal, man and woman into space. When the Soviet Union learned that the US was planning the first spacewalk, its efforts became focused on beating the US to it. Leonov underwent 18 months of intensive weightlessness training and, while the US spacewalk was scheduled for June, Leonov was first blasted into orbit on 18 March 1965.

STEPPING INTO the UNKNOWN

On 18 March 1965, Soviet cosmonaut Alexei Leonov successfully completed the first spacewalk while travelling on board Voskhod 2. The USSR may have beaten the Americans to the feat, but it was far from an easy ride

★ Written by Jon Bauckham ★

As Alexei Leonov climbed out through the inflatable airlock of Voskhod 2, he paused to admire the Earth's natural splendour. Aside from the protective visor of his helmet, he was the first human to be presented with an unencumbered view of the planet in all its glory. "It felt as if I were almost motionless, floating above a vast blue sphere draped with a colourful map," Leonov would later recall. "For a few moments, I felt totally alone in this pristine new environment, taking in the beauty of the panorama below me with an artist's eye."

On the ground, thousands of people across the Soviet Union were watching Leonov's spacewalk unfold in a series of grainy black-and-white images, courtesy of a camera perched on top of the craft. It was a seismic moment in the history of spaceflight, and another resounding victory for the USSR, which just five months earlier had completed the first multi-crew mission with the launch of Voskhod 1.

But what viewers would not realise is that Leonov's mission had been plagued with technical problems from start to finish, to the extent that its crew had nearly perished on several occasions. And they certainly weren't aware that Leonov's spacesuit was fitted with a cyanide capsule had he not been able to make it back on board.

From its inception the Voskhod 2 project had taken a huge personal toll on those involved. The pressure to beat the Americans in undertaking extravehicular activity, or 'EVA', rested heavily on the shoulders of chief Soviet space engineer Sergei Korolev, who sought to accomplish the task as soon as possible.

While plans were already in motion to develop the superior Soyuz spacecraft, time restrictions forced Korolev to adapt the older Vostok model, as he had done with Voskhod 1. Although this second mission would only carry two cosmonauts rather than three, it would still be a tight squeeze, with no room for ejector seats. If anything went wrong during the crucial minutes after liftoff, both occupants would be condemned to death.

In embarking on such a dangerous endeavour, the Soviets required two cosmonauts of the highest calibre. Alongside 30-year-old Leonov, the authorities opted for 39-year-old commander Pavel Belyayev, who had seen action during the Second World War. Plucky, smart and determined, both men belonged to the elite cohort of 20 fighter pilots that had entered training alongside Yuri Gagarin in 1960, beating over 2,000 candidates in the process.

Yet it was still an immense risk. Voskhod 2's 'Volga' airlock had only been tested during an unmanned flight in February 1965, during which control room errors had forced the craft to self-destruct. Leonov would be the guinea pig – and potentially a sacrificial lamb.

Early on 18 March 1965, Belyayev and Leonov were driven to the launchpad of the Baikonur Cosmodrome in Kazakhstan. After urinating on the wheels of their bus for good luck, the duo climbed aboard their spacecraft, with the elder Belyayev leading the way. Then, at 7:00am UTC, Voskhod 2 made its daring ascent, attached to a powerful R-7 rocket – intended to take the cosmonauts higher than ever attempted before. As the rocket separated from the spacecraft, the pair were in orbit around the Earth.

As Voskhod 2 sailed high above the Crimea, the big moment finally arrived. After connecting special breathing apparatus to his 'Berkut' (Golden Eagle) spacesuit, Leonov exited the cabin and waited as Belyayev depressurised the airlock. When the process was complete the outer hatch opened, and Leonov climbed into the vacuum of space.

Having positioned a film camera on top of the airlock, Leonov pushed himself to the end of his five-

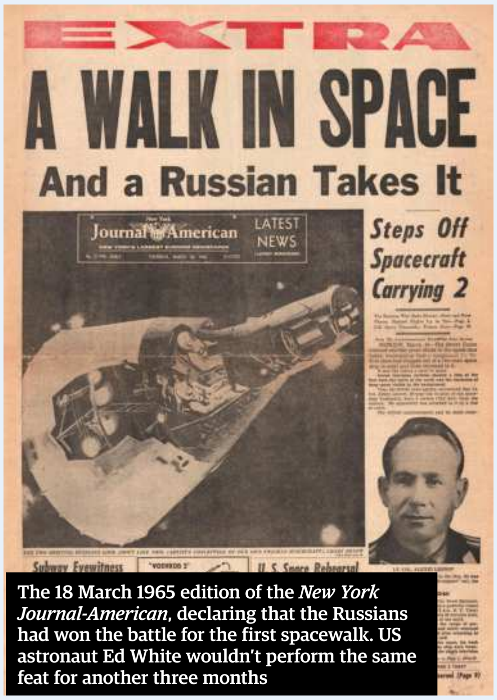
Pavel Belyayev (left) and Alexei Leonov (right) in the cabin of Voskhod 2 prior to liftoff. Having originally been designed for one occupant, it was a tight squeeze

> "As he tried to activate the shutter on his separate body camera, Leonov noticed that his spacesuit was ballooning"

metre (16-foot) long tether, attached to his midriff like an umbilical cord. Despite a few clumsy manoeuvres he soon regained control, and was able enjoy ten euphoric minutes of EVA.

But, as he tried to activate the shutter on his separate body camera, Leonov noticed that his spacesuit was ballooning. Suddenly his fingers were no longer inside his gloves and his feet had become separated from their boots, leaving him with minimal control over his movements. To make matters worse his body temperature was soaring, and he began to flounder.

Back at ground control there was confusion. What on Earth - or indeed space - was Leonov up to?



EXTRA

A WALK IN SPACE

And a Russian Takes It

Journal-American

LATEST NEWS

Steps Off Spacecraft Carrying 2

The 18 March 1965 edition of the *New York Journal-American*, declaring that the Russians had won the battle for the first spacewalk. US astronaut Ed White wouldn't perform the same feat for another three months

Sensing imminent disaster, the live broadcast was cut short, and audiences were instead presented with innocuous light entertainment. Yet Leonov, keen not to cause any alarm, maintained his silence. As he clung onto the airlock entrance, it was then that he decided to vent air from his spacesuit using a small valve fitted to the exterior.

This was an incredibly dangerous - if not reckless - decision. By doing so he ran the risk of suffering fatal decompression sickness. But then again, if he didn't come up with a solution soon, Belyayev would be forced to jettison the airlock and leave his comrade stranded regardless.

"The exhilaration I had felt just minutes before evaporated," remembered Leonov. "Bathed in sweat with my heart racing, I knew I could not afford to panic. But time was running out."

Eventually Leonov was able to climb back inside the Volga, retrieving the film camera along the way. However, instead of entering with his feet as previously instructed, he had gone in head first. To his cost, he then discovered that the outer hatch had not closed properly, and he would now have to manoeuvre his entire body around and seal it himself. He eventually succeeded - but not before almost passing out from heatstroke.

On one level the mission had been a success, yet in reality the duo's woes had only just begun. Most alarmingly, the process of sealing the hatch had confused Voskhod 2's climate-control system, flooding the cabin with pure oxygen - a problem they were forced to solve manually. As the crew of Apollo 1 would later discover to their cost in 1967, even the slightest spark in this environment would ignite a fatal fire.

Then, when it was time to return to Earth, the automatic landing system also ground to a halt. As a result their only way of making it back home was for Belyayev to use the craft's 'Vzor' navigation device, which he could only access by positioning

A WEAPON FOR THE WILDERNESS

LANDING MEANT A NEW FIGHT FOR SURVIVAL

As Voskhod 2 came back to Earth on 19 March 1965, it seemed as though Pavel Belayev and Alexei Leonov's ordeal was finally over. However, they had overshot their intended landing site by more than 321 kilometres (200 miles) and found themselves knee-deep in snow in the Siberian 'taiga'.

Heavily fatigued and without any heating, their only option was to wait inside the husk of the capsule and hope that their radio signals worked. No one - not even ground control - knew what had befallen the two cosmonauts, and Soviet television stations had been playing the strains of Mozart's *Requiem*, as if pre-empting awful news. Thankfully Voskhod 2's distinctive red parachutes were spotted by a helicopter, but they would still have to wait until at least the next morning until a rescue party could bail them out.

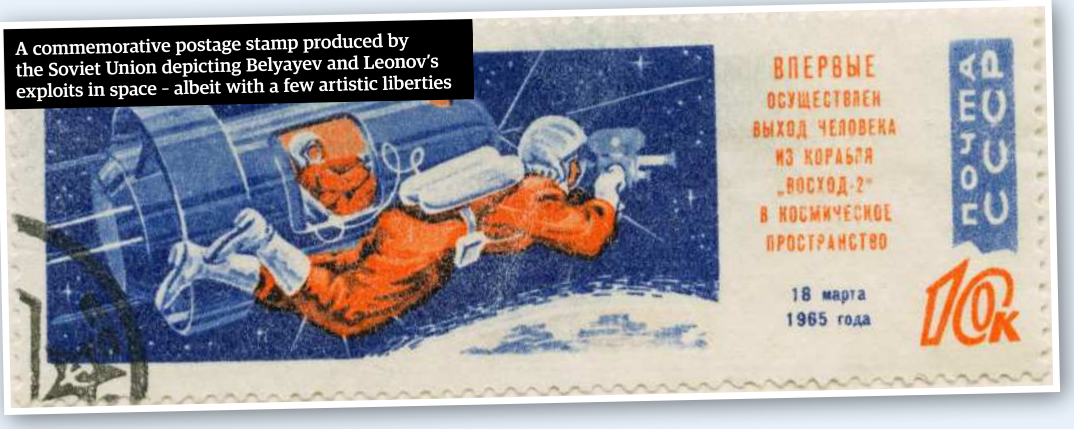
Yet one of the biggest concerns on Leonov's mind was not the risk of frostbite, but the prospect of coming face-to-face with bears and wolves. Having grown up in Siberia himself he knew that it was mating season, and that his meagre 9mm pistol would be hopeless in the event of an attack.

Luckily, passing predators weren't treated to a cosmonaut meal that night, but Leonov's fears were sufficient enough for the Soviet space programme to develop a survival pistol known as the TP-82, designed especially for crew members to carry on their missions.

Much like a James Bond gadget, the bizarre weapon bore a number of functions. As well as being able to fire shotgun rounds, rifle ammunition and distress flares, the TP-82 also featured a detachable machete concealed within a canvas sheath.

Somewhat remarkably, the TP-82 remained a key component of cosmonaut survival kits taken on Soviet and Russian space missions right up until the mid-2000s, when it was phased out after ammunition was discontinued. Today crews instead carry semi-automatic weapons, but still have to undergo survival training to prepare them for the prospect of crash-landing in the wilderness.

Alexei Leonov (left) and Pavel Belyayev (right) ski towards their rescue helicopter after spending two nights in the Siberian forest



A commemorative postage stamp produced by the Soviet Union depicting Belyayev and Leonov's exploits in space – albeit with a few artistic liberties

himself across the couches, with Leonov holding his legs in place.

But, due to a 46-second delay in returning to their seats, the spacecraft's centre of mass shifted, and the men were sent hurtling hundreds of miles away from their intended landing site towards an area of Siberian wilderness known as the 'taiga'. Worse still, the equipment module had failed to separate from the main capsule, sending the craft into a spin. It wasn't until the connecting straps burnt up close to the Earth's surface that it finally came away.

At 9:02am on 19 March, Voskhod 2 touched down in an area of forest nestled among the Ural Mountains, where the men were eventually spotted by a helicopter. However, having landed in such a densely wooded area, Belyayev and Leonov were forced to spend the night in sub-zero conditions, huddling together for warmth. It wasn't until the following morning that the pair were met by a rescue party, which constructed a hut and allowed the men to spend a cosier second night in the taiga, before skiing to a chopper eight kilometres (five miles) away.

It may have been a troublesome ordeal, but the USSR had taken yet another major scalp in the Space Race, and the cosmonauts were lauded as heroes. Although the Americans would only have to wait three months for Ed White to complete a spacewalk with Gemini 4, the apparent success of Voskhod 2 was a huge ideological victory for the Soviet people – especially when aided by the State propaganda machine.

"Nobody explained anything to the public," said Leonov. "As far as they knew, our mission had passed without incident. As far as those in power were concerned, the crises were a matter of a discussion and analysis by the relevant technical committees."

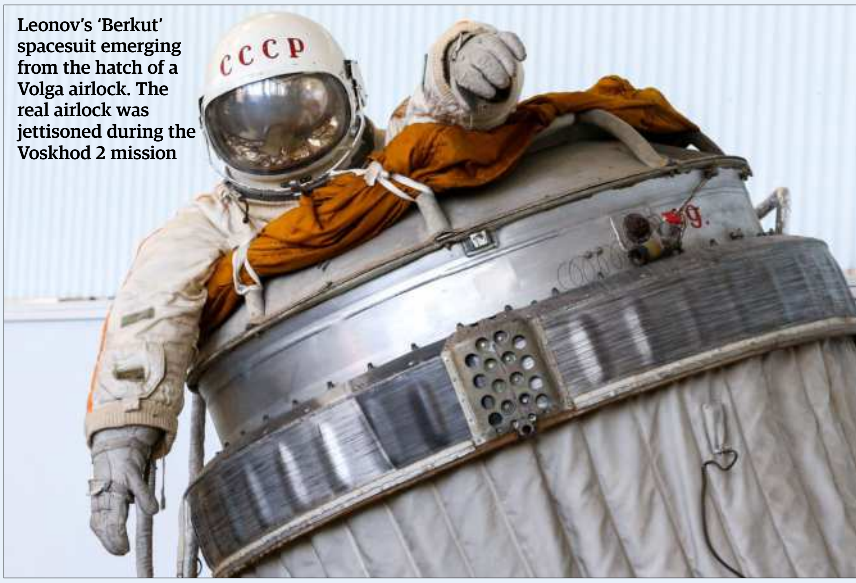
Regardless of the whitewash, it was impossible to deny the scale of human achievement. Leonov's endeavour was proof to scientists and engineers on both sides of the divide that it was possible to build space stations, carry out vital repairs and dock with other spacecraft. This would ultimately be proven when Leonov led the Soyuz 19 mission a decade later, linking up with an Apollo crew in mid-orbit.

Tragically, Belyayev would not live to see his friend complete the feat, dying of peritonitis in 1970 – a seemingly trivial end for a man who had commanded one of the most dangerous quests in history. Yet by virtue of taking part in Voskhod 2, his legacy was certainly secure.

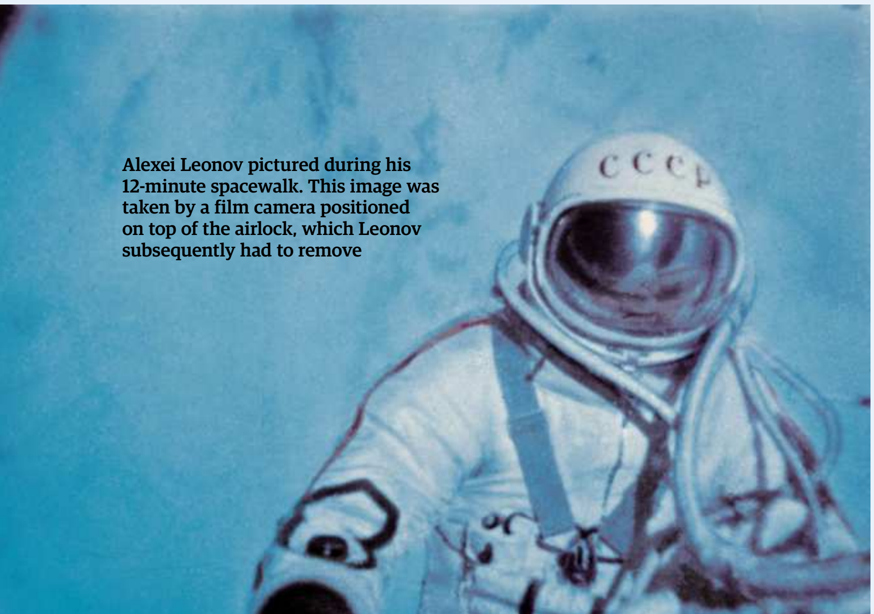
Leonov donates a painting depicting his spacewalk to Moscow's Tretyakov Gallery in 2006. A talented artist, Leonov took coloured pencils and a sketchpad on board Voskhod 2 in 1965

© Alamy, Getty Images

Pavel Belyayev (left) and Alexei Leonov (right) take the bus to the launchpad along with Vladir Komarov (centre), who commanded the successful Voskhod 1 mission five months previously



Leonov's 'Berkut' spacesuit emerging from the hatch of a Volga airlock. The real airlock was jettisoned during the Voskhod 2 mission



Alexei Leonov pictured during his 12-minute spacewalk. This image was taken by a film camera positioned on top of the airlock, which Leonov subsequently had to remove

Crowds in Moscow welcome Belyayev and Leonov back to Earth following the Voskhod 2 mission. It was another resounding Soviet victory in the Space Race

While Eisenhower started the Space Race on the back foot, his successors eventually built towards the ultimate propaganda victory

The PRESIDENTS and the SPACE RACE

As the cold war heated up, US presidents were forced to tackle the most hotly contested theatre of them all: space

Written by Hareth Al Bustani

Despite conquering the Axis together, the United States and USSR emerged from World War II as natural rivals. Boasting seemingly incompatible economic and political systems, they immediately sought to gain the upper hand over one another. Harry Truman understood this well, pouring money not only into weapons, but also into aeronautical developments – resulting in several technological breakthroughs.

However, with both sides in possession of weapons of mass destruction, the natural progression of the developing arms race was the theatre of space. The tone of the ensuing Space Race was a barometer of the mood of the times. Eisenhower's failure to keep up with the Soviets caused hysteria among the American populace, and directly fuelled Kennedy's challenge to put a man on the Moon – which seemed like the only way to decisively turn the tide. Though Kennedy believed space exploration could become a unifying force between the US and USSR, his untimely assassination stopped this notion dead in its tracks.

His successor, Johnson, who had previously played a crucial role in forming the US space programme, believed that the Space Race was one of the most important avenues of the Cold War. However, he became increasingly distracted by the Vietnam War and dissent at home – leaving the country on the cusp of achieving Kennedy's dream.

Although Nixon's first year in power saw the US finally land on the Moon, having dealt the Soviets a crushing blow, he pursued a more frugal path – launching the space shuttle programme and ushering in a new age of cosmic cooperation.

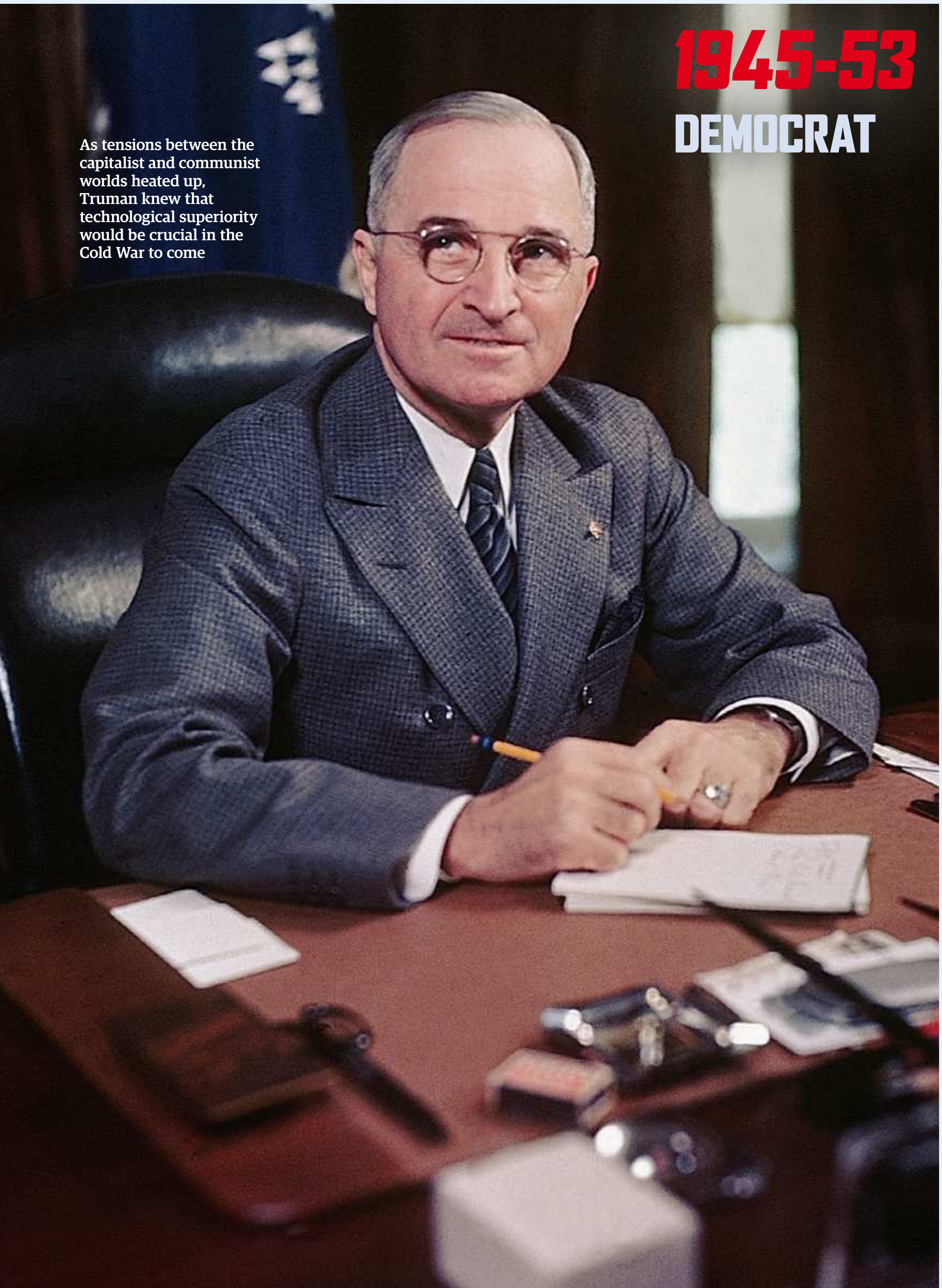
NACA, the precursor to NASA, partnered with Bell Aircraft to develop the X-1, the world's first supersonic aircraft

GLAMOROUS GLENNIS

Before leaving office, Johnson sent out the Apollo 8 Earthrise photo to world leaders, ironically receiving a thank-you note from Ho Chi Minh

Despite his troubled tenure, Lyndon B Johnson was among the most influential of America's presidents

HARRY S TRUMAN



1945-53

DEMOCRAT

As tensions between the capitalist and communist worlds heated up, Truman knew that technological superiority would be crucial in the Cold War to come

Harry Truman ascended to the presidency after the death of Franklin D Roosevelt at a defining time in both World War II and the Cold War. As he said himself, "I felt like the Moon, the stars, and all the planets had fallen on me." Just months later, a new superweapon would fall upon the Japanese cities of Hiroshima and Nagasaki with his approval. Though the devastating nuclear bombs would put an end to the bloodiest war the world had ever seen, it ushered in a new, even more dangerous, era.

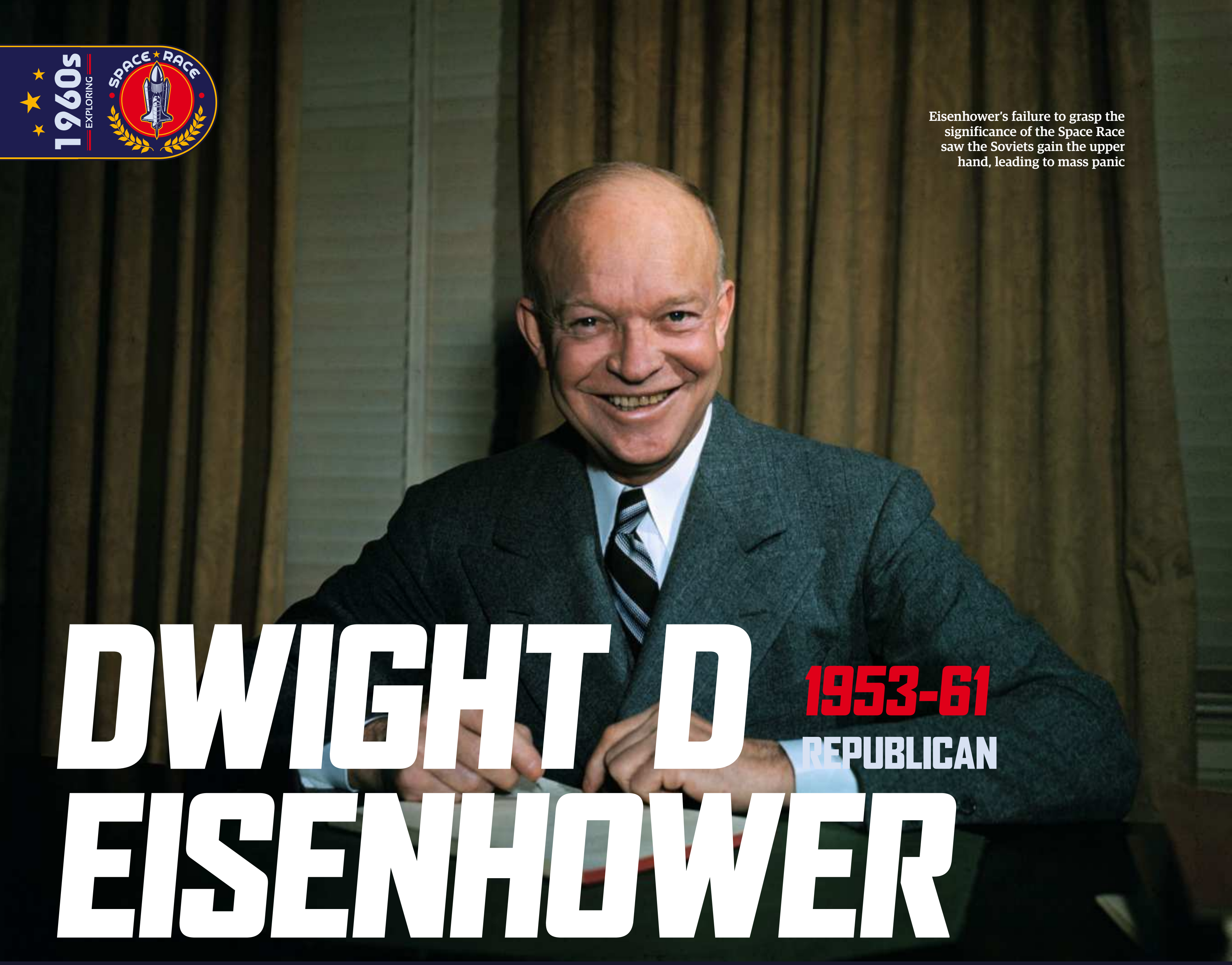
After the war's close, the US and USSR emerged as the two world's dominant superpowers. Though the latter had lost tens of millions of lives, it grossly expanded its territory, engulfing the countries it 'liberated' from Germany. At the upper echelons of both political systems was a deep sense of mistrust - the opposing ideologies of capitalism and communism seemed to be mutually exclusive, natural enemies in a bipolar world.

In this perilous new environment, the National Advisory Committee for Aeronautics (NACA) turned its attention to trying to develop supersonic flight. Reporting directly to Truman, NACA partnered with the US Air Force and Bell Aircraft to create, for the first time, its own plane from scratch. The first supersonic flight was achieved in 1947, with Captain Chuck Yeager piloting the X-1. Four years later, a NACA engineer would pioneer the coke bottle shape, forming the basis of most modern fighter jets.

Simultaneously, in 1946, the RAND Corporation commissioned a study that called for the development of a military satellite system. Two years later, Bell Telephone Labs invented the transistor, which was far lighter and smaller than existing vacuum tubes - allowing for more compact technology. With the subsequent invention of long-range boosters, the development of military satellites now seemed a distinct possibility. In 1951, the US Air Force launched Operation Feedback, the country's first satellite programme, geared at developing satellites for military observation.

Having previously chaired a subcommittee during the formation of the Civil Aeronautics Act of 1938, President Truman maintained a distinct sense of wonder for aeronautics. Speaking at the Aero Club of Washington, he said: "49 years ago it was hard to get people to believe that the Wright brothers had actually flown an airplane at all." In awe of the field's subsequent progress, he added: "As I have said many a time before, I wish I could see the development of the next half century. I won't quite be able to reach that far, but I am going to go as far as I can."

By the end of his presidency, China had been consumed by its Communist Revolution, and half of Korea had followed suit. With the USSR having developed its own atom bomb, the two global superpowers were now pouring money into arms programmes, chasing the hydrogen bomb and churning out as many weapons of mass destruction as they could. As the threat of mutually assured destruction loomed ever-closer, the aeronautics and satellite programmes that Truman left behind would take centre stage.



Eisenhower's failure to grasp the significance of the Space Race saw the Soviets gain the upper hand, leading to mass panic

DWIGHT D EISENHOWER

1953-61

REPUBLICAN

Eisenhower stepped into office at a time of great uncertainty. While domino theory had Americans terrified of the Red Menace abroad, the paranoia of Senator Joseph McCarthy's communist witch-hunt would continue until his death in 1957.

That year, the International Geophysical Year challenged governments to launch satellites into space to map the Earth's surface. However, what was intended to provide a unifying force in the name of scientific discovery instead sparked the Space Race. To the United States' horror, the Soviets beat them to the punch, successfully launching the Sputnik satellite that October.

Eisenhower tried to dismiss the achievement, calling it "one small ball in the air" that there was no need to "grow hysterical about". Despite the limited scientific value of Sputnik, it introduced the space age to Americans in the most harrowing light possible - one dominated by the Soviets.

The president's efforts to sweep the Soviet accomplishment aside were not well received by a public who assumed it indicated the Soviets had also developed intercontinental ballistic missile technology. For his complacency, Eisenhower was perceived as delusional, absent from office and unaware of the facts on the ground. To make matters worse, just a month later the Soviets followed it up by launching a dog, Laika, into space in the 508-kilogram Sputnik 2 spacecraft.

In response, Senate majority leader Lyndon B Johnson launched a subcommittee to investigate the United States' defence and space programmes, using it as a platform to skewer Eisenhower and the Republican Party. One of his aides, George E Reedy, said: "The simple fact is that we can no longer consider the Russians to be behind us in technology - it took them four years to catch up to our atomic bomb and nine months to catch up to our hydrogen bomb. Now we are trying to catch up to their satellite."

To this, Eisenhower reportedly said: "Lyndon Johnson can keep his head in the stars if he wants. I'm going to keep my feet on the ground." Despite this bravado, desperate to turn the tide, in December, Eisenhower decided to test out the Project Vanguard booster in front of a crowd of media onlookers. Unfortunately, the rocket only rose three feet before erupting into flames. The next month, however, a team of German scientists successfully launched the American Explorer 1 satellite, using Juno 1 boosters, at Cape Canaveral in Florida - which detected Van Allen radiation belts - followed by Vanguard 1 in March.

While the president, eager to gain the upper hand, wanted to direct his space programme through the Department of Defense, his science advisor James Killian and vice-president, Richard Nixon, convinced him to create a civilian agency - one that would promote transparency and international collaboration. The result was the National Aeronautics and Space Administration, or NASA, which absorbed NACA and soon after launched the Mercury programme, aiming to send a human into low orbit and bring him home safely.

Eisenhower still insisted that prospective astronauts be drawn from the military, while also attempting to dismiss the notion of entering a "space race". Programmes, he argued, would have to be justified by military, scientific or technological value, above and beyond propaganda value. One early casualty of this approach was the Apollo Moon programme, an exercise so costly and painstaking, the NASA chief told the president: "If we fail to place a man on the Moon before 20 years from now, there is nothing lost." In response, Eisenhower defunded it - leaving America's Space Agency wondering what its future role in the space race might be.

JOHN F KENNEDY

1961-63

DEMOCRAT

While Eisenhower maintained a confused policy towards the space programme, John F Kennedy was clear - he was going to take the fight to the Soviets. He wanted to not only establish the US space programme as the world's most advanced, but to utterly overwhelm the USSR.

That April, the Soviets racked up yet another win when Yuri Gagarin became the first human to travel in space. Just a week later, Kennedy's attempt to topple the Cuban government at the Bay of Pigs failed spectacularly. If he hoped to put the Soviets on the back foot, it was time to go for the jugular.

With the president desperate for "dramatic results", Vice President Lyndon B Johnson discussed the issue with NASA, the Department of Defense, Congress, and experts from across both industry and academia. Wernher von Braun, a key architect of the American space programme, told Johnson: "We have a sporting chance. With an all-out crash programme, I think we could accomplish this objective in 1967-68."

Johnson's subsequent report stated that the US needed to step up its space exploration as a matter of "national prestige". In May, the president addressed Congress, announcing: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be so difficult or expensive to achieve."

To the Soviets, who preferred to develop their projects in secret, the speech seemed of little consequence - but it was to have profound, far-reaching effects on the international space race. Kennedy immediately boosted NASA's budget by almost 90 per cent, and by a further 101 per cent the following year.

Despite his ambitions, Kennedy still reserved some hope that the pursuit of space exploration could provide a unifying force between the two superpowers - a mutually beneficial frontier to resolve tensions. In June, at a summit in Vienna, Austria, he asked Soviet premier Nikita Khrushchev, "Why don't we do it together?" Though Khrushchev initially seemed open to the idea, the next day he responded with a resounding "no". The president's wife had a little more luck at dinner when she asked the premier if he could send her one of the puppies the USSR had put into space - and two months later, she apparently received a "terrified small dog" at the Oval Office.

The president had a particular affinity for astronauts - John Glenn frequently visited him at his private family compound in Massachusetts. When Glenn embarked on the Friendship 7 mission, orbiting Earth three times, the president was among two million Americans who watched the launch live on television.

To Kennedy, the Apollo programme would become a symbol of American enterprise and ambition, stating: "We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard." In a private meeting with NASA's administrator James Webb, he reiterated that the space programme was "whether we like it or not, a race". Reaching the Moon before the Russians, he added, was "the top priority of the agency and except for defence, the top priority of the United States government - otherwise, we shouldn't be spending this kind of money, because I'm not that interested in space".

However, after the peaceful resolution of the potentially apocalyptic Cuban Missile Crisis, Kennedy's tone shifted slightly. Speaking at the United Nations in September 1963, he floated the idea of a joint Moon expedition, asking his audience, "Why should man's first flight to the Moon be a matter of national competition?"

Unfortunately, on the cusp of this spirit of reconciliation, he was assassinated just months later. However, although his tenure was brief, it was impactful enough for his successor Johnson to name the Cape Kennedy launch site in his honour, a name it still bears today.

Eager to recover prestige in the Space Race, Kennedy challenged the US to send a man to the Moon by the decade's end

Though Johnson played a leading role in the development of the US space programme, as president he became increasingly distracted by the catastrophic Vietnam War and civil strife

LYNDON B JOHNSON

1963-69

DEMOCRAT

Lyndon B Johnson had played a crucial role in the US space programme long before inheriting Kennedy's presidency. He saw the Space Race as exactly that - a race. While Eisenhower had tried to brush off the significance of Sputnik, Johnson was furious. "From space," he said, "the masters of infinity would have the power to control the Earth's weather, to cause drought and flood, to change the tides and raise the levels of the sea, to divert the gulf stream and change temperate climates to frigid."

As Senate majority leader, he helped fast track the formation of NASA through Congress, and he later proved crucial in forging President Kennedy's own outlook of the Space Race. As vice president, he had written to Kennedy, asserting that "dramatic accomplishments in space are being identified as a major indicator of world leadership". Ascending to the presidency, he further declared: "I do not believe that this generation of Americans is willing to resign itself to going to bed each night by the light of a communist Moon."

In March 1965, he admitted to senator John McClellan that the Soviets had so far been "running rings" around the US, but that "we think we got a fair chance to keep up with these people by '70". Looking forward, he elaborated: "This research is the most important thing we can do. John, 75 per cent of the things we will be making 25 years from now we have never heard of now. That's how fast the world changes."

Johnson played an instrumental role in the UN's Outer Space Treaty, envisioned during Kennedy's administration, which would govern the use and exploration of outer space. While guaranteeing the freedom to explore the universe, it prohibited the placement of weapons of mass destruction in space, or conventional weapons on celestial bodies - in effect, setting the rules of engagement for the Space Race. Celestial bodies and their natural resources were designated the "common heritage of all mankind", and could not be claimed.

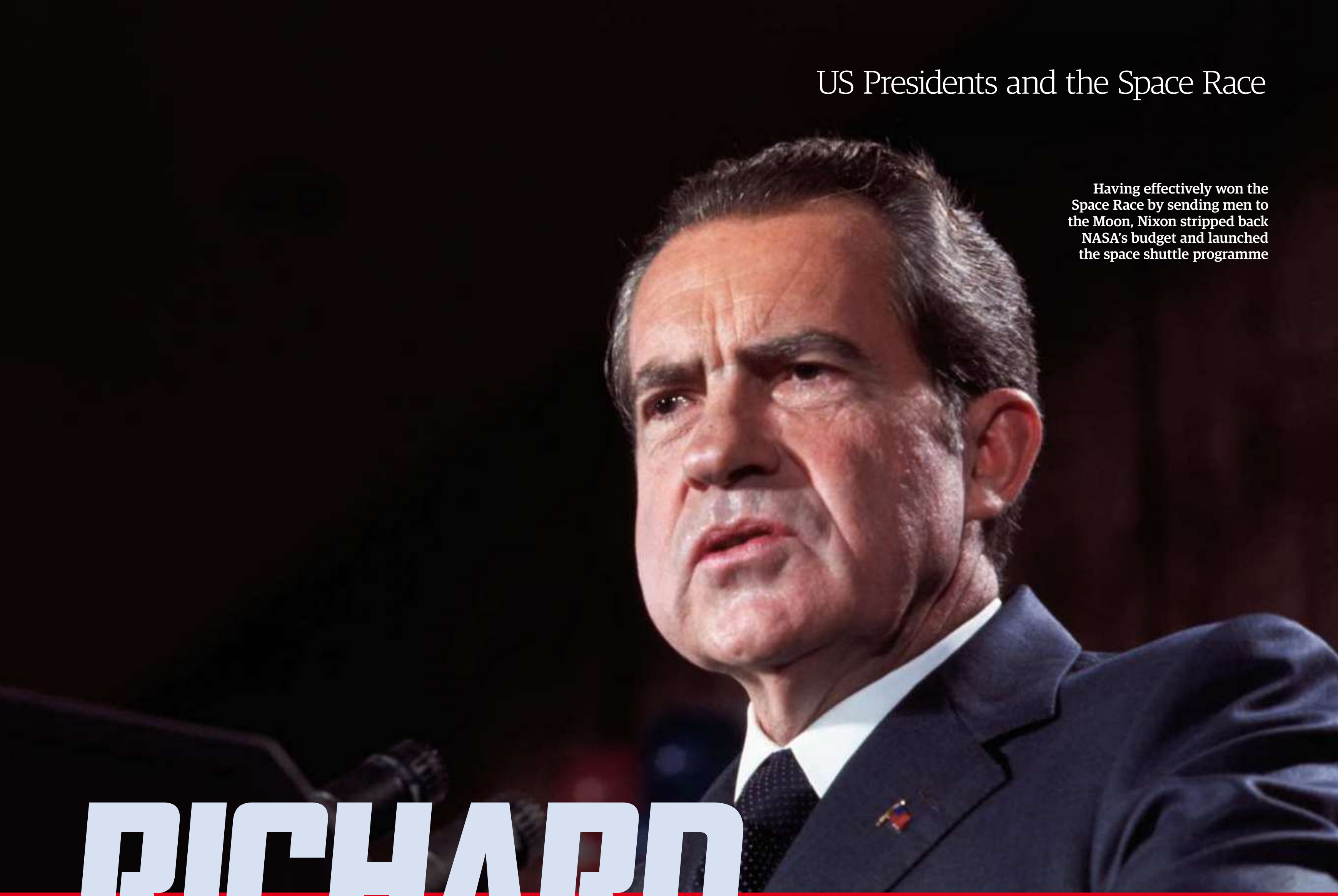
The treaty was signed the same day as a fire cut short the Apollo 1 mission to land three men on the Moon, killing the vessel's crew members. Rather than being consumed by the failure, John persevered, encouraging NASA to look into what went wrong and build on it going forwards.

Though Johnson had once been a leading proponent of the space programme, as his presidency became mired in the quagmire of the Vietnam War and civil strife, his ability to afford time and attention to it dwindled. He would later comment that he spent more time in the space field up to 1963 than he did after becoming president.

During the more difficult days of tenure, he visited the Michoud Assembly Facility in New Orleans to see Saturn boosters being assembled. There, the fatigued president lamented to astronaut Wally Schirra, "It's too bad. We have this great capability, but instead of taking advantage of it, we'll probably just piss it away."

With the country deeply embroiled in an unpopular foreign war, Johnson's NASA budget rapidly plummeted, meaning that the agency could focus on little other than the Apollo mission. Having chosen not to stand for re-election, he left office dejected in January 1969, leaving behind a thoroughly fleshed-out lunar programme.

Among his final acts in office was to send out a copy of Earthrise - a photograph taken the previous Christmas Eve by the crew of Apollo 8, the first manned spacecraft to orbit the moon and return back to earth - to all world leaders. Souring what might have otherwise proven a defiant final moment in power, he received a thank-you card, from none other than North Vietnamese president Ho Chi Minh.



Having effectively won the Space Race by sending men to the Moon, Nixon stripped back NASA's budget and launched the space shuttle programme

RICHARD NIXON

1969-74

REPUBLICAN

Richard Nixon took office at an auspicious time - in July of that year, the US finally achieved Kennedy's dream, as Apollo 11's Neil Armstrong and Buzz Aldrin stepped onto the Moon. As far as American prestige was concerned, they had reached the pinnacle of scientific exploration - nothing the Soviets had done, or could do, would hold the weight of such an accomplishment, televised for all the world to see. The propaganda victory was not lost on Nixon, who was said to have watched intently, clapping and proclaiming "hooray," as Armstrong emerged onto the lunar surface.

Speaking to the astronauts live on the Moon via phone, he reflected: "As you talk to us from the Sea of Tranquillity, it inspires us to redouble our efforts to bring peace and tranquillity to Earth." Gambling on the mission's success, he not only welcomed the team back to Earth in person, but pre-arranged a nine-day tour of capitals across the world.

Later that year, Nixon became the first president to attend a space launch, with Apollo 12. The president reportedly loved astronauts, who he saw as genuine American heroes, hosting them regularly at dinners at the White House - and immersing himself in their stories.

However, any hope that the Moon landing would inspire Nixon to set a new, bold goal for the decade to come was in vain. Though the country was wild with excitement, Nixon rejected NASA's plans for a huge fleet of space stations and a decades-long project for a mission to Mars. He did not even respond to the Mars plan for six months.

Forgoing wonder, he instead pursued a sense of practicality, in 1970 stating that space activities should be considered "part of a continuing process and not as a series of separate leaps, each requiring a massive concentration of energy". In truly bureaucratic language, he added: "Space expenditures must take their proper place within a rigorous system of national priorities." Perhaps in direct opposition to Kennedy's spirit, Nixon said that while the United States' approach to space must continue to be bold, "it must also be balanced" - that the country should "work to reduce substantially the cost of space operations".

However, when the crew of the Apollo 13 mission returned to Earth safely, he was there in Hawaii to greet them, with Medals of Freedom, pronouncing: "Greatness comes not simply in triumph but in adversity. It has been said that adversity introduces a man to himself."

Over the course of his presidency, the NASA budget fell from four percent of the federal budget to just one per cent - leading to the end of the Apollo programme. Despite his frugality, Nixon did approve the space shuttle programme. While his budget and technical advisors implored him to seek restraint, it was election year, and he sought to win over California's aerospace workers.

When he met with the NASA administrator to announce the project, demonstrating a curiosity about the potential of the technology, he allegedly stressed both civilian and military applications - expressing an interest in using shuttles to aid in disasters, dispose of nuclear waste and collect solar power, and beam it to the earth. The president was also said to have relished the democratisation of the astronaut experience, with ordinary people able to fly in shuttles alongside astronauts.

In 1972, Nixon signed an agreement with Soviet premier Alexei Kosygin, which ushered in a new age of cooperation in space, culminating in the joint Apollo-Soyuz Test Project. Though Nixon would eventually be forced out of office by the Watergate scandal, his views on space would dictate American policy for decades to come.

© Alamy, Getty Images

LEARNING to FLY

Project Gemini formed a bridge between NASA's first Mercury flights and the Apollo Moon programme

The historic flight of Soviet cosmonaut Yuri Gagarin on 12 April 1961 plunged the United States into a crisis of confidence - if their Cold War rival was so far ahead in space, what else might they be capable of? The Mercury programme would be America's immediate response, but President John F Kennedy realised that a long-term solution was needed, refocusing US space policy on an ambitious target that would, over several years, allow NASA to fight its way back into the Space Race. Six weeks later, Kennedy announced a new goal in space to Congress - America was going to the Moon.

NASA officials knew that getting there would call for an array of new techniques and technology. Aside from powerful new rockets, potential schemes for putting people on the Moon all required rendezvous and docking of spacecraft and components in orbit - flight manoeuvres far beyond the Mercury capsule's basic capabilities.

With the Apollo spacecraft still on the drawing board, there was a clear need for an intermediate vehicle - something capable of supporting more than one astronaut on longer missions, manoeuvring in orbit and testing various procedures that might be needed en route to the Moon. This new spacecraft was to be Project Gemini.

Once the basic requirements had been established, the Gemini spacecraft was developed and built at breakneck speed. Although superficially similar in appearance to a scaled-up Mercury capsule, it was far more capable. A pressurised 're-entry module' seated two astronauts side-by-side in a cockpit environment that was designed in consultation with the Mercury astronauts (particularly Gus Grissom) and appealed to their test-pilot mindset.

Beneath this in a conical stack sat two more elements - the 'retrograde module' whose rockets would be used to return from orbit, and the 'equipment module' carrying batteries, propellant, water and other supplies. An important advance came with the introduction of fuel-cell technology that could generate electricity using liquid oxygen and hydrogen, reducing the need for heavy batteries and permitting longer-duration flights. Thruster nozzles dotted across the surface of all three elements allowed a Gemini craft to change its orbit and orientation in space.

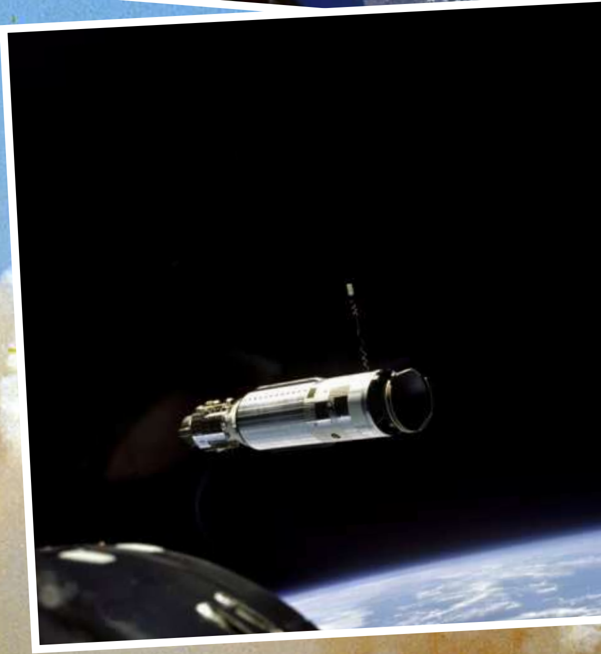
The first Gemini spacecraft was launched on 8 April 1964 using a Titan II rocket. This derivative of the US Air Force's Titan ballistic missile, a fairly simple and reliable rocket whose fuels ignited on contact (avoiding the need for a complex ignition system), was used for launches throughout the Gemini programme.

Fitted with test equipment in place of a crew, the Gemini 1 spacecraft appeared to perform well in orbit, but was not designed for recovery. A second test, in January 1965, assessed the splashdown procedure and allowed engineers to see how the spacecraft had coped with re-entry to the atmosphere.

With no significant problems encountered, NASA gave the go-ahead for a manned launch. Gemini 3 launched on 23 March 1965, pairing Grissom with a new astronaut, John W Young. The shakedown flight lasted a mere three orbits, but the spacecraft systems worked perfectly and the only significant incident occurred when Young produced a corned-beef sandwich he had smuggled aboard, sharing a few bites with Grissom. Despite being reprimanded by his superiors afterwards, Young would go on to have an illustrious NASA career, flying in both the Apollo and Space Shuttle programmes.

The path was now clear for a more ambitious mission in the form of Gemini 4. Crewed by two new astronauts, James McDivitt and Ed White, this June flight lasted a little over four days. During the mission, the astronauts successfully carried out a range of on-board experiments, although attempts to change

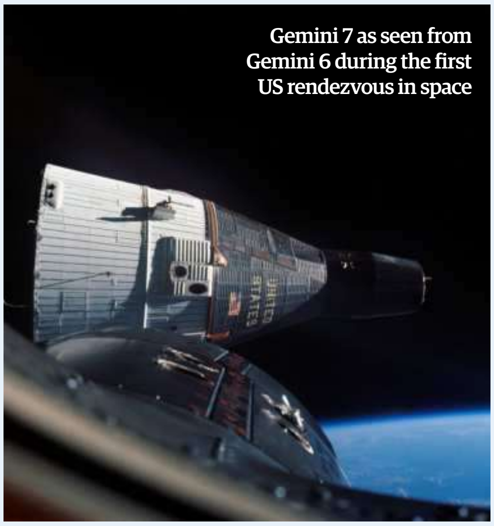
UNITED STATES



orbit and rendezvous with the spacecraft's own Titan II upper stage ended in failure.

However, such problems were outshone by an iconic success, as White opened his hatch and became the first US astronaut to walk in space. White remained tethered to the spacecraft throughout his 'Extra-Vehicular Activity' (EVA), but he was able to float free and manoeuvre using a 'zip gun' that fired a jet of gas in one direction to push him in the other. Although the Soviets had achieved their first spacewalk a few months before, White's longer EVA went far more smoothly, and delivered stunning photographs of an astronaut floating in space – at last, it seemed, NASA was catching up in the Space Race.

That message was reinforced when Gemini 5, launched in August 1965, spent eight days in orbit, smashing the five-day space endurance record previously held by the Soviet Vostok 5. The mission paired Mercury veteran L Gordon Cooper with newcomer Charles "Pete" Conrad Jr, and was the first to match the duration of the planned lunar flights. Not everything went smoothly, however – issues with the fuel cells meant electricity had to be rationed – a planned rendezvous with an unmanned 'pod' was scaled back to a more basic manoeuvring test, and other experiments had to be abandoned (leading Conrad to remark at one point that he wished he'd brought a book with him to pass the time).


Gemini 7 as seen from Gemini 6 during the first US rendezvous in space

> "Gemini 5 spent eight days in orbit, smashing the five-day space endurance record previously held by the Soviets"

Although many aspects of Gemini had now proved successful, pressure was mounting for the next mission to pull off the long-awaited orbital rendezvous. Gemini 6, planned for launch on 25 October, was intended to rendezvous with a special unmanned 'Agena target vehicle' (ATV) that would launch shortly ahead of it. Mercury astronaut Wally Schirra and his colleague Thomas Stafford were sitting aboard their spacecraft ready for launch when news came through that the ATV had been lost after an explosion.

With Gemini 7 already planned for a December launch on a 14-day endurance mission, it seemed that Gemini 6 had lost its launch window, and the opportunity for a successful rendezvous would have to wait until the following year. But then Frank Borman and Jim Lovell, the Gemini 7 crew, made a daring suggestion: why not use their own spacecraft as Gemini 6's rendezvous target? After some convincing, NASA officials signed off on the idea – Gemini 6 (redesignated Gemini 6-A) launched on 15 December, towards the end of Borman and Lovell's mission. And this time, everything went smoothly, with Schirra and Stafford steering their capsule to within 30 cm (12 in) of Gemini 7.

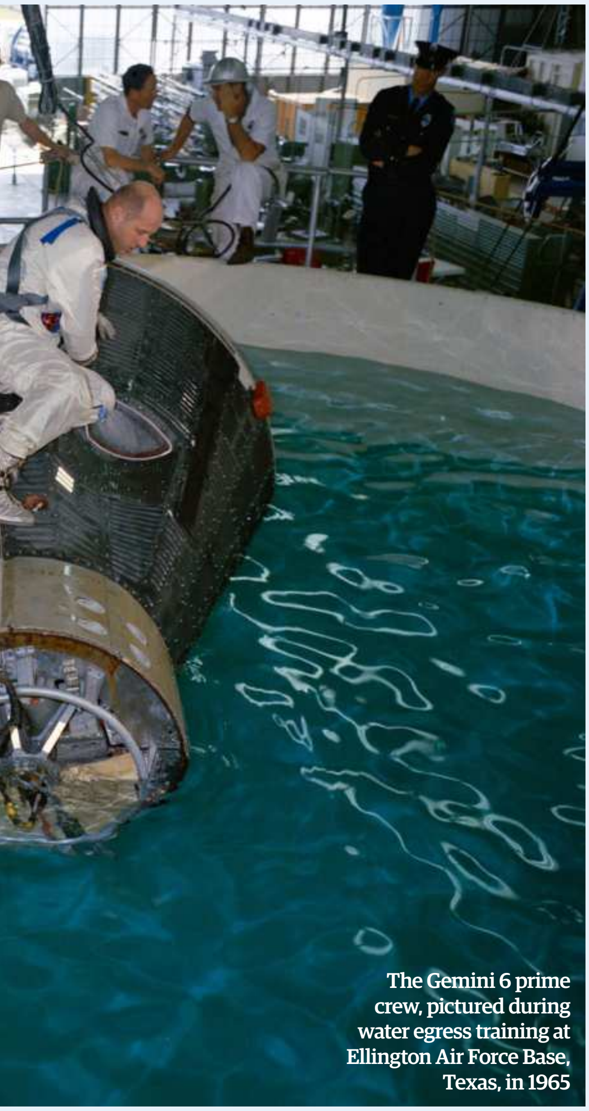
1966 saw ever-more daring missions for Gemini, as NASA geared up for the planned first flights of the Apollo spacecraft the following year. Gemini 8, launched in March, was crewed by two newcomers who would both go on to command Apollo lunar missions – Neil Armstrong and David Scott. They docked successfully with an ATV at last (the first ever docking in orbit), but shortly afterwards a jammed thruster set the linked spacecraft into a dangerous spin that forced them to cut the mission short.

Gemini 9-A (the designation indicated the use of its reserve crew, Thomas Stafford and Gene Cernan, after the primary crew died in an air crash) also hit a

number of problems. When the spacecraft approached its ATV docking target in June, it found that the protective shroud around it had failed to come away, making docking impossible. Cernan also had trouble accessing an 'astronaut manoeuvring unit' jetpack that he was supposed to wear during a spacewalk.

Fortunately, this was the programme's last major setback. Gemini 10, launched the following month with John Young and Michael Collins aboard, not only docked with its own ATV, but then steered to a rendezvous with the Gemini 8 target vehicle, allowing Collins to inspect the abandoned spacecraft during an EVA. Gemini 11 saw Pete Conrad and Richard Gordon set a new altitude record of 1,374 km (854 miles), and even generated artificial gravity by tethering the spacecraft and its ATV, then setting them in a slow spin around each other.

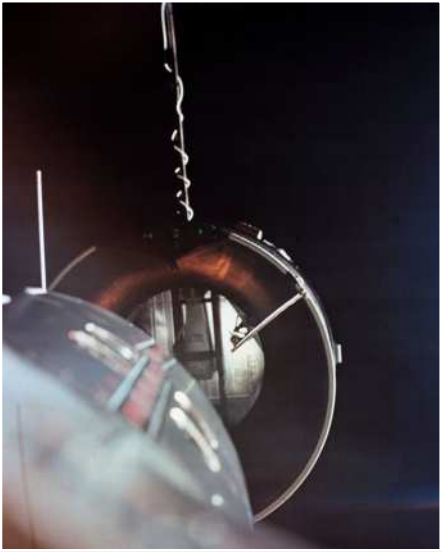
The twelfth and final Gemini mission was brief but equally ambitious. Crewed by Buzz Aldrin and Jim Lovell, it spent four days in orbit rehearsing many of the docking and rendezvous techniques that would be required by the Apollo missions. In addition, Aldrin carried out a complex two-hour spacewalk using new handgrips to clamber around the capsule and practice servicing it in space. By the time Gemini 12 splashed down on 15 November 1966, the stage was set for the debut of Apollo.

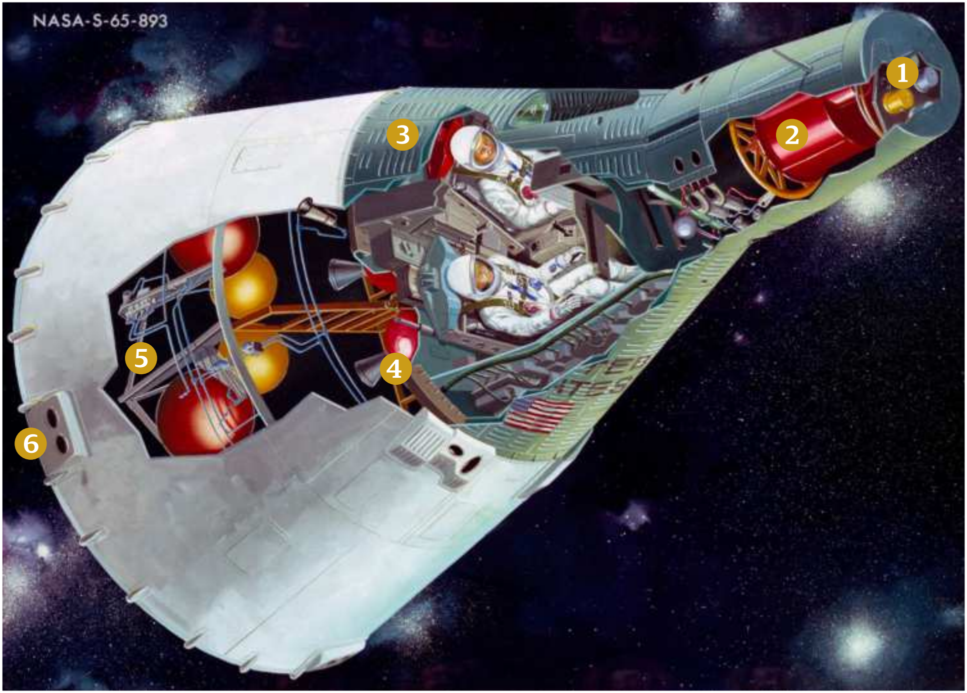


The Gemini 6 prime crew, pictured during water egress training at Ellington Air Force Base, Texas, in 1965

DOCKING IN SPACE

GEMINI'S DOCKING SYSTEM CONSISTED OF A PROBE MOUNTED ON THE END OF THE MANNED SPACECRAFT THAT LOCKED INTO A CONICAL RECEPTOR ON THE END OF THE TARGET VEHICLE. GEMINI 11 PILOT RICHARD GORDON COMPARED IT TO THE MID-AIR REFUELLING MECHANISM ON A JET FIGHTER. ONCE SECURELY DOCKED, CONTROLS IN THE GEMINI CAPSULE ALLOWED THE ASTRONAUTS TO CONTROL THE ENGINE AND THRUSTERS ON THE TARGET VEHICLE.





1 RENDEZVOUS ANTENNA

This antenna extended from the spacecraft during docking operations and slid into a cone on the target vehicle.

2 PARACHUTE SYSTEM

During re-entry, Gemini employed a small drogue before its main parachutes – early plans to use a paraglider system were abandoned.

3 CREW HATCHES

Twin hatches allowed access for the astronauts – EVAs were carried out simply by the astronaut opening the hatch and standing up in his seat.

4 RETROGRADE MODULE

Situated behind the re-entry module, the retro module housed four solid rockets. During re-entry, the spacecraft reversed its orientation to point backwards along its orbit, and fired these rockets to slow down.

5 EQUIPMENT MODULE

The rearmost Gemini module contained equipment to power and sustain the spacecraft on missions that were going to be up to two weeks long, including batteries and fuel cells, water and oxygen.

6 ATTITUDE CONTROL THRUSTERS

Thrusters positioned at various points around the Gemini spacecraft could be fired in sequence to change the vehicle's orientation and manoeuvre in space.

© NASA, KSC, James McDivitt

Buzz Aldrin (pictured) and Neil Armstrong spent 21 hours on the lunar surface during Apollo 11

The APOLLO PROGRAM

The trailblazing NASA missions that took us to the Moon

In the late 1950s, the US and the Soviet Union were both racing to reach a major milestone in spaceflight: put humans on the Moon then return them safely back to Earth. In July 1969, NASA launched Apollo 11, carrying astronauts Neil Armstrong, Buzz Aldrin and Michael Collins. Armstrong's famous words, broadcast from the lunar surface, clinched the title for the Americans and changed the course of human history: "One small step for a man, one giant leap for mankind."

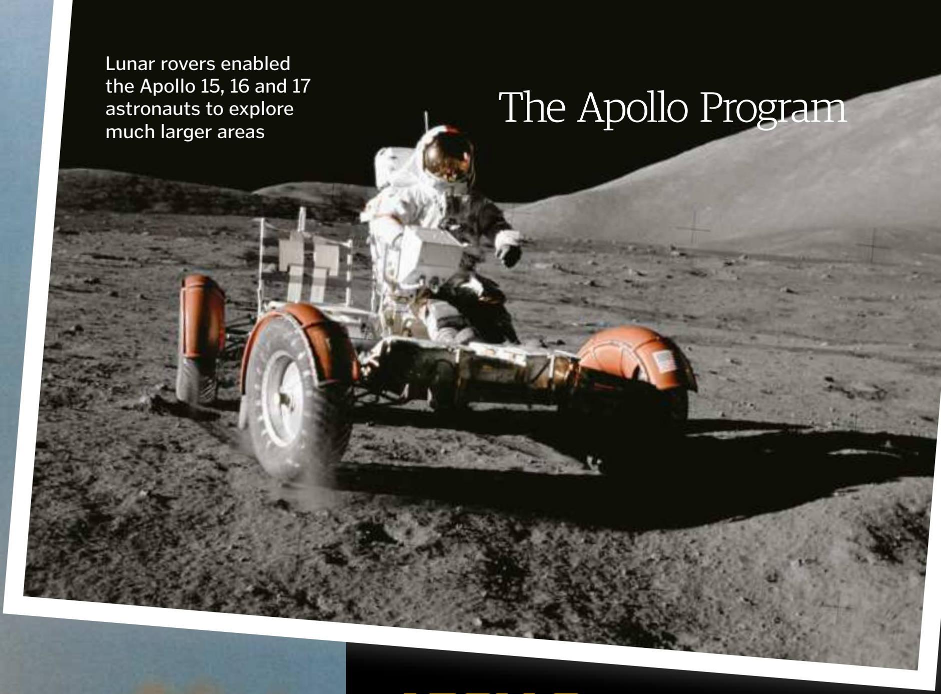
NASA was formed in 1958 and the Apollo Program was only its third major spaceflight initiative. In order to achieve this ambitious goal, it designed and built a whole new breed of vehicles. The Saturn V rocket, which eventually launched all six manned lunar landings, was taller than the Statue of Liberty and weighed as much as 400 elephants. It was more powerful than any rocket that came before it.

The astronauts themselves rode in the Apollo spacecraft, a small portion at the top of the enormous launch vehicle. Once the rocket had put Apollo on course for the Moon it fell away, leaving the spacecraft to complete the four-day journey and return to Earth.

From 1969 to 1972, 12 astronauts walked on the Moon, some staying for as long as three days to conduct detailed surveys and experiments on their surroundings. Over the six missions, almost 400 kilograms of lunar samples were collected and brought back to Earth. The astronauts also installed six observatories on the surface of the Moon, which operated for many years after the surface was free of human footsteps. The wealth of data has not only transformed our understanding of the Moon but also hinted at the history of Earth and the entire Solar System.

Saturn V launched Apollo 15 from NASA's Kennedy Space Center in Florida

> "Saturn V was more powerful than any rocket that came before it"



Lunar rovers enabled the Apollo 15, 16 and 17 astronauts to explore much larger areas

APOLLO DISCOVERIES

THE MOON IS LIFELESS

No signs of life, past or present, were found in the lunar samples collected during the Apollo missions.

THE MOON IS ASYMMETRICAL

The Moon's crust is thicker on the far side, while most of its volcanic basins lie on the near side.

THE YOUNG MOON MELTED

Early in its history, the Moon was heated to create a molten ocean of magma, topped with a rocky crust.

ASTEROIDS SHAPED THE MOON

The large, dark basins on the Moon were created by huge asteroid impacts, which were later filled by flowing lava.

MOON RUBBLE TELLS A STORY

The Moon is covered in rubble that contains clues to the Sun's activities over the last 4 billion years.

APOLLO MISSIONS

A HISTORY OF NASA'S LUNAR EXPLORATION

APOLLO 1

- Never launched
- Manned
- Test flight, destroyed during pre-flight test

APOLLO 2 (RE-DESIGNATED)

- 25 August 1966
- Unmanned
- Test flight, success

APOLLO 3 (RE-DESIGNATED)

- 5 July 1966
- Unmanned
- Test flight, success

APOLLO 4

- 9 November 1967
- Unmanned
- Test flight, success

APOLLO 5

- 22 January 1968
- Unmanned
- Test flight, success

APOLLO 6

- 4 April 1968
- Unmanned
- Test flight, engine failures

APOLLO 7

- 11 October 1968
- Manned
- Earth orbit, success

APOLLO 8

- 21 December 1968
- Manned
- Lunar orbit, success

APOLLO 9

- 3 March 1969
- Manned
- Earth orbit, success

APOLLO 10

- 18 May 1969
- Manned
- Lunar orbit, success

APOLLO 11

- 16 July 1969
- Manned
- Lunar landing, success

APOLLO 12

- 14 November 1969
- Manned
- Lunar landing, success

APOLLO 13

- 11 April 1970
- Manned
- Lunar landing, aborted on outward flight

APOLLO 14

- 31 January 1971
- Manned
- Lunar landing, success

APOLLO 15

- 26 July 1971
- Manned
- Lunar exploration, success

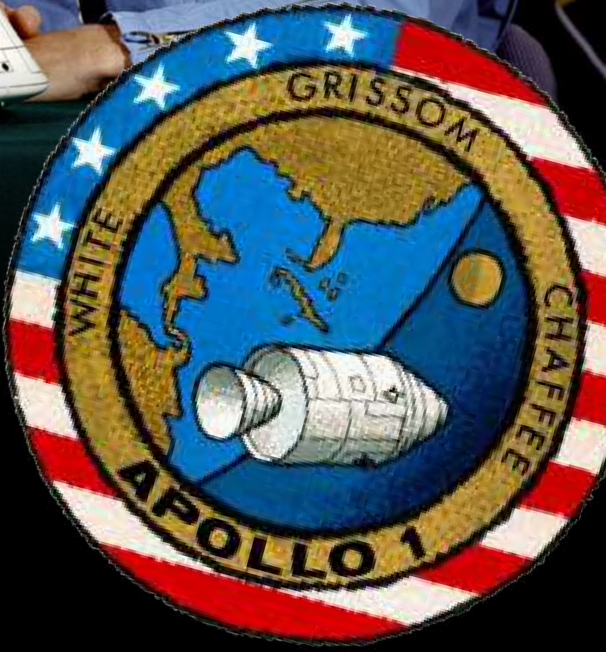
APOLLO 16

- 16 April 1972
- Manned
- Lunar exploration, success

APOLLO 17

- 7 December 1972
- Manned
- Lunar exploration, success

From left to right, the crew of Apollo 1; Edward H White, Virgil I Grissom and Roger B Chaffee



Apollo 1 was scheduled to be the first manned mission of the Apollo program

The TRAGEDY of APOLLO 1

How a routine test cost three men their lives, becoming the United States' first fatal disaster

Written by Baljeet Panesar

The Apollo program was supposed to signal a new era of human spaceflight exploration. Its aim was noble – to land man on the Moon. The Mercury and Gemini programs of the 1950s and 1960s had proved that humans could fly to space, and live and work in a spacecraft. Yet even after their previous success, the events that unfolded on 27 January 1967 would change the course of the American space program.

Nearly six years before, President John F Kennedy had announced to Congress of his aim "of landing a man on the Moon and returning him safely to the Earth" by the end of 1969, giving the US less than nine years to achieve this ambitious goal. At this point the USSR was leading the Space Race; on 12 April 1961 cosmonaut Yuri Gagarin became the first person to fly to space and he completed one orbit of the Earth in the 108-minute flight.

Alan Shepard became the first American in space less than a month later on 5 May 1961, but it was John Glenn who became the first American to orbit the Earth, completing three orbits on 20 February 1962 in the Friendship 7 capsule. By 1966, the US had overtaken the USSR, having demonstrated that it was possible to change the orbit of a spacecraft, completing the first space rendezvous, space docking, and showing that humans could safely perform tasks outside a spacecraft.

The crew of Apollo 1, originally designated AS-204, was made up of Virgil 'Gus' Grissom, an experienced astronaut from the Mercury and Gemini programs; Edward White, the first American to walk in space, and Roger Chaffee, an astronaut on what was to be his first spaceflight. The crew was selected by Deke Slayton, the director of flight crew operations, in 1966. The mission was to be the first crewed flight of the command and service module to Earth orbit, and the first mission with a three-person crew. It was to launch on 21 February 1967, until a fatal fire broke out in the capsule.

The Apollo 1 crew during water egress training in June 1966

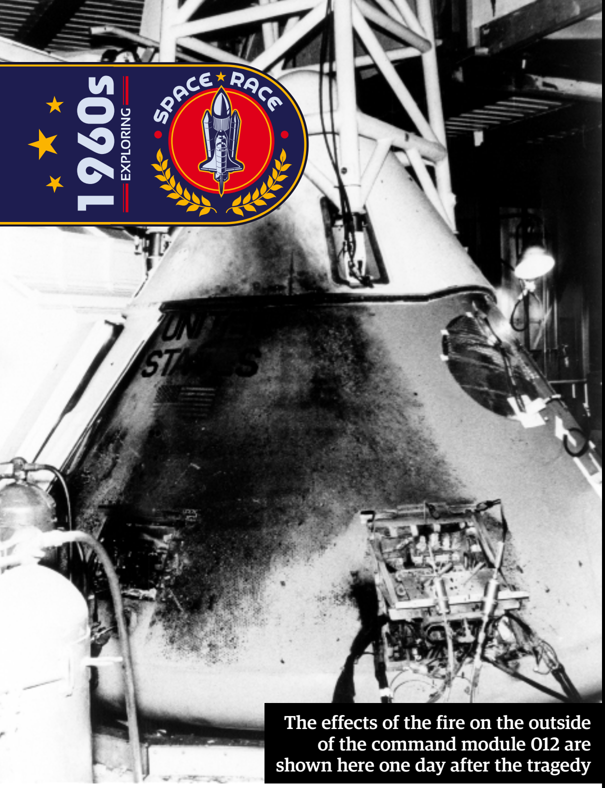
Sitting atop a Saturn 1B launch vehicle – the predecessor to the Saturn V – at Cape Kennedy Launch Complex 34, at 13:00 EST (18:00 UTC) Grissom, Chaffee and White entered Apollo Command Module 012 wearing fully pressurised suits. Once the hatch had been installed and sealed, the craft was filled with pure oxygen at a pressure of 16.7 pounds per square inch (psi) – normal atmospheric pressure is 14.7 psi. The crew was due to complete a routine, pre-launch test known as a 'plugs-out' test, a test that NASA had been performing since Project Mercury. It was essential for ensuring that the February flight did not need to be postponed, and it was overseen by mission control in Houston, Texas. This test would allow the crew to determine whether the spacecraft could operate on its own internal power for their upcoming two-week mission; neither the spacecraft nor launch vehicle had any fuel – hence the name 'plugs-out'.

Although NASA was conducting research into oxygen-rich fires and had experienced several fires of that kind themselves, the test was not thought to be hazardous. Even though there were minor problems that immediately became apparent, such as Grissom reporting a smell like that of sour buttermilk in his oxygen supply, these did not cause any significant alarm. The most important and persistent issue was the difficulty in communication that the spacecraft and control centre were experiencing.

Five and a half hours later, the US would suffer its first fatal disaster of its space programme. At 18:31:04.7 EST (23:31:04.7 UTC), a cry of "fire!" was heard over the communications system. The flames could be seen within the spacecraft, taking just ten seconds to engulf Spacecraft 012, and lasting less than 20 seconds since it was reported. Temperatures in some places of the capsule reached over 530 degrees Celsius (1,000 degrees Fahrenheit). Although the crew attempted to open the inward-opening hatch – a process that would require a minimum of 90 seconds to open under normal conditions – under

"The flames could be seen within the spacecraft, taking just ten seconds"

Apollo 1 crew training in a simulator on 19 January 1965



The effects of the fire on the outside of the command module 012 are shown here one day after the tragedy

the high-pressure environment in the cabin, it was impossible and the crew were trapped. Roughly 15 seconds after the report of the fire, the capsule ruptured, causing the oxygen to escape and the fire to subside. Members of the ground team had tried to save them, but their efforts were hampered by the dense smoke and intense heat of the flames. Finally, after roughly five minutes, ground crew were at last able to open the two-piece hatch, but it was too late - the three members were lost. Toxic gases had been produced in the capsule causing the crew to lose consciousness and perish.

Immediately after the fire, NASA established the Apollo 204 Review Board and the US Senate conducted its own investigation into the Apollo 1 accident. Investigators at NASA took two months to take apart the command module, and the review board submitted its investigation in April 1967. The latter determined that the most probable source of the fire - the investigation could not conclusively determine the ignition source - was an electric arc that had been produced beneath Grissom's seat. The use of combustible materials, such as nylon and Velcro, and the pure oxygen atmosphere, which was originally used to reduce the weight of the spacecraft, caused the fire to spread rapidly through the cabin. The US Senate released its report a year later, stating that "everyone associated with the design and test of the spacecraft simply failed to understand fully the danger and cooperative effect of an ignition source, the combustible materials, and the pure oxygen atmosphere in the sealed spacecraft cabin".

The fire caused the Apollo program to be suspended for over 18 months, threatening its future with less than three years left to fulfil Kennedy's goal of reaching the Moon. At a time of great shock, sadness, disbelief and possibly embarrassment, Congress recommended that "NASA continue to move the Apollo program forward to achieve its goal" as "the most fitting memorial this country can leave these men is the success if the Apollo program - the goal for which they gave their lives".

To ensure that the Apollo 1 tragedy would not be repeated, major design, materials and procedural changes were made. After a series of flammability tests, it was determined that ground tests were to use an 'enriched air' mix of 60 per cent oxygen and

THE PHILLIPS REPORT

THE SECRET NASA REPORT THAT CONGRESS DIDN'T EVEN KNOW EXISTED

Having faced competition from 13 other companies, on 28 November 1961, NASA awarded North American Aviation (NAA) – the company behind the P-51 Mustang, the B-25 Mitchell and the X-15 rocket plane – the contract to build the Apollo command and service module (CSM).

Four years later, between 22 November and 6 December 1965, Major General Samuel C Phillips, Apollo program director at NASA, at the request of George E Mueller, NASA associate administrator for manned space flight, completed a detailed investigation to determine why the CSM and Saturn S-II stage were behind schedule and over budget. This highly critical (and confidential) analysis, known as the Phillips Report – the most official criticism of a NASA contractor of its day – detailed various recommendations that would hopefully get the Apollo Moon project back on schedule. The review was submitted to the president of the NAA John Leland Atwood on 19 December 1965.

As the prime contract of the spacecraft, the NAA was partly blamed for the tragedy of Apollo 1, and the report became of even greater importance when NASA administrator James E Webb appeared to have no knowledge of it. During the Congressional investigation of the fire, Phillips and Mueller had initially denied knowing of the report's existence, and lead to junior Senator Walter Mondale publicly revealing the document, which had been leaked to him in February 1966. Although the Senate committee concluded that "the findings of the [Phillips] task force had no effect on the accident, did not lead to the accident, and were not related to the accident", Mondale accused NASA of "evasiveness, lack of candor, the patronising attitude displayed toward Congress, the refusal to respond fully and forthrightly to legitimate congressional inquires, and the solicitous concern for corporate sensitivities at a time of national tragedy".

Members of the NASA Administration before the Senate in May 1967

A stage of the Saturn 1B launch vehicle that was due to launch Apollo Saturn-204

The remains of the interior of the Command Module after the fire

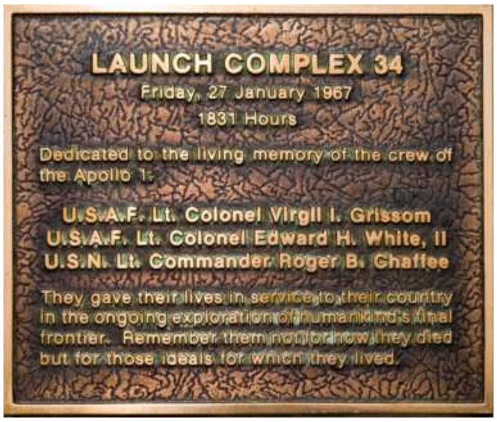
"The fire caused the Apollo program to be suspended for over 18 months, threatening its future"

The three astronauts enter the command module to complete training for mission Apollo Saturn-204

40 per cent nitrogen to minimise the spread of a fire. 100 per cent oxygen would then be used once the mission had been launched. Flammable materials were removed or replaced with self-extinguishing versions. The inward-opening, two-piece hatch was replaced by a single outward-opening hatch, which could be opened from the inside in seven seconds and by the ground team in ten seconds, making them much easier to open in another emergency if ever there was another. In fact, this design feature is still used in spacecraft today.

Further, the lack of emergency preparedness also contributed to the accident. As the test was thought to be non-hazardous, emergency equipment such as appropriate gas masks, as well as fire, rescue and medical personnel, were not present. The board made several recommendations based on this, including that ground personnel should become trained in emergency procedures.

A plaque serves as a tasteful memorial to the fallen crew. The launch complex was last used for the Apollo 7 mission



LAUNCH COMPLEX 34

Friday, 27 January 1967

1831 Hours

Dedicated to the living memory of the crew of the Apollo 1:

U.S.A.F. Lt. Colonel Virgil I. Grissom

U.S.A.F. Lt. Colonel Edward H. White, II

U.S.N. Lt. Commander Roger B. Chaffee

They gave their lives in service to their country in the ongoing exploration of humankind's final frontier. Remember them not for how they died but for those ideals for which they lived.

These modifications allowed NASA to return Neil Armstrong and Buzz Aldrin to Earth after landing on the Moon in July 1969, ensuring that no other Apollo mission would result in someone's death and, after considering the astronauts' concerns, no other loss of life would occur for another 19 years. Despite the publicity of the tragedy, the Soviet Union stayed markedly quiet in response.

Eventually the aims of Apollo 1 were successfully achieved by Apollo 7, the back-up crew for the former mission, in October 1968. In 2017, the 50th anniversary of the disaster, NASA honoured the three fallen heroes by opening a tribute exhibit at the Kennedy Space Center in Florida. Entitled 'Ad Astra Per Aspera – A Rough Road Leads to the Stars', the name is a fitting tribute to the crew who lost their lives in the name of space exploration so that those after them could safely reach the stars. But they were also honoured back in 1969 when, in memory of Chaffee, Grissom and White, the Apollo 11 astronauts left the Apollo 1 patch on the Moon – a symbol of the human sacrifice made in order to reach and land on the lunar surface.

As we continue to push the boundaries of space exploration, the ill-fated Apollo 1 – and the lessons that were learnt – is just as relevant today as it was in 1967. Grissom once said: "If we die, we want people to accept it. We are in a risky business, and we hope that if anything happens to us, it will not delay the program. The conquest of space is worth the risk of life". Their sacrifice to reach the Moon, and others who have lost their lives during spaceflight, will never be forgotten.

THE SOVIET APOLLO 1

ABOUT SIX YEARS BEFORE THE APOLLO 1 ACCIDENT, A SOVIET COSMONAUT ALSO SUFFERED THE SAME FATE

In the 1960s Soviet Union's space flight program, cosmonaut training wasn't much different to that of NASA; both agencies had to prepare their men for the physical, mental and emotional challenges they would face in space. As part of their training, cosmonauts would be isolated in a 'silence chamber', and the aim of the test was to determine how the individual would cope in solitude with very little stimuli. Each session could last for several hours or over a week, but the cosmonauts were not told how long they would be in the chamber for.

Valentin Vasiliyevich Bondarenko, a 24-year-old Soviet fighter pilot, was the 17th cosmonaut to enter the chamber, and it was pressurised to 68 per cent oxygen to represent the conditions in Vostok 1 in Earth orbit. On 23 March 1961, he competed his ten-day experiment. But a fire started after an alcohol-soaked cotton wool pad that Bondarenko had used landed on an uncovered coil. Combined with the high-pressure oxygen environment, the flames spread quickly, like in the Apollo 1 tragedy. However, unlike Apollo 1, Bondarenko was rescued alive, but he died of his injuries the day after, less than three weeks before Gagarin's iconic flight. The details of the accident were not published in the West until the 1980s.

In similar circumstances to the crew of Apollo 1, Bondarenko perished during a training exercise

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APOLLO'S FIRST CREWED FLIGHT

Astronaut Walt Cunningham, who piloted the first successful crewed mission in the Apollo programme, explains the dangers he faced when making his way into space

★ Interviewed by Gemma Lavender ★

BIOGRAPHY

Walt Cunningham

Walt Cunningham was the Lunar Module pilot on the Apollo 7 mission. Before his career with NASA, Cunningham was a fighter pilot with the US Marine Corps and successfully gained a doctorate in physics. After his flight into space with Walter Schirra Jr and Donn Eisele, Cunningham worked in a management role for the space station Skylab.

Could you tell us why you became an astronaut?

I can tell you, it wasn't for the money. My starting salary when I went to work for NASA was $13,050 a year. When I left eight years later, I had worked my way up to $25,000. I did sit down once and calculate that if I got paid 50 cent a mile, I would have made $2.24 million.

I should mention that we weren't covered by NASA's flight insurance. If we had been, the payment would have been too high for the other employees of NASA. But overall, let me tell you, it was one of the world's greatest jobs. The Sixties through to the Seventies was the golden age of manned space flight. It was very much like the Twenties, which saw the development of aeroplanes. We weren't flying planes with silk scarves but, you know, we felt like it.

Did you always want to be an astronaut? What does it take to become an astronaut?

Well, in 1963 I was a US Marine Corps fighter pilot, working on a doctorate in physics at the University of California, Los Angeles (UCLA). When I applied to NASA to become an astronaut, it turned out I was one of 770 qualified applicants and one of the eventual 14 that would later go into space.

Well, some good people didn't make it. I will never forget we were down to 34 people when we showed up for our eight-day physical. I thought that my friend, a Navy lieutenant who went by the name of Bob Shoemaker, was a sure thing in being selected.

Well, when we left after eight days, I went home and Bob went home. But Bob was out of the running to become an astronaut - he had been diagnosed with bone tuberculosis. It took him six months to get his wings back and he was then transferred to Vietnam. The next time I saw him, it was in a picture and he was being led through a Vietnamese village with his arms tied behind his back. Bob was shot down in Vietnam.

So who does make it? I think we were all bright, healthy, in good physical condition, motivated and self-starters, with a feeling of strong self-confidence. We knew where we were going and how we were going to get there. I think a lot of people would call that ego [laughs]. At the time, spaceflight was considered too tough for anyone that was over 30. It was thought that a younger fighter pilot could endure the wear and tear of space travel. It was a young man's game. Or so we thought.

Today, the average age in astronaut office is 45 years of age. Back in those good old days we were hired based on experience and qualifications. I had military training and so had spent much of my life facing risk. In essence, we didn't shy away from the unknown and we were willing to take a risk. Surviving a very dangerous profession, where we were well aware of where we were going and how we would get there. And, we depended on each other with our lives.

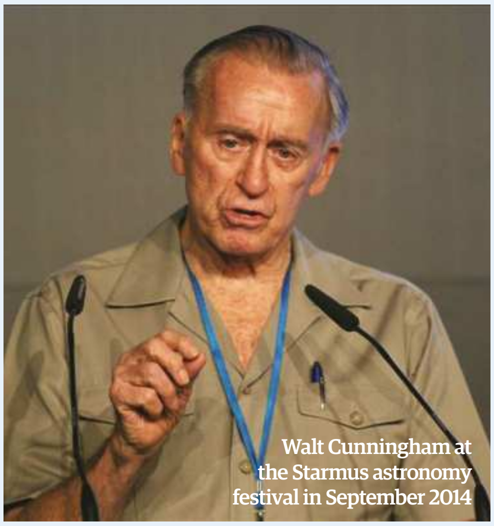
The first Apollo mission ended in disaster with its astronauts being killed in a cabin fire. Were you afraid that something similar would happen?

Three men [Gus Grissom, Edward White and Roger Chaffee] paid the price of progress and I lost three good

Cunningham says that the next chance for dangerous adventure is the exploration of Mars

Cunningham was one of 14 astronauts selected by NASA in 1963 friends in that fire. But was I afraid of the mission? No. The only thing I can recall having was a fear of failure. Each of our team had the same thought: "If this mission fails, it won't fail because of me". We weren't afraid of accepting the challenge – we had already accepted that. We were afraid to be found lagging behind our peers.

Apollo 7 was really the first step in a plan to land man on the Moon. That plan had five giant steps. Apollo 7 was built for test and operations, systems and spacecraft, then Apollo 8 had to overcome the psychological barrier of leaving the Earth's gravitational field and heading to the Moon. Apollo 9 had to overcome another barrier in testing the Lunar Module in Earth orbit, so its astronauts [James McDivitt, David Scott and Rusty Schweickart] spent a lot of time in the Lunar Module separated from the Command/Service Module. Apollo 10 was a complete dress rehearsal of landing on the Moon.


Walt Cunningham at the Starmus astronomy festival in September 2014

Did the Apollo 1 disaster set the programme back a considerable amount?
Absolutely. The Apollo programme schedule slipped and it was eventually cancelled. We also used a different model of space capsule from that time on. It took 21 months to recover and make all of the changes necessary that we thought could have caused that fire. There were a lot of operational changes on the spacecraft in the meantime.

So Apollo 7 was considered – at the time – to be a very ambitious effort to make up for lost time. It was planned for 11 days to test all of the propulsion and all of the spacecraft systems, all of the docking, all of the rendezvous manoeuvres, ground systems… you name it, it was tested. To this day, Apollo 7 is one of the most ambitious and most successful test flights of one of the first new flying machines ever. That spacecraft was near perfect. It was a wonderful accomplishment.

What reception did you get when you returned ?
As astronauts, we were at the tip of the spear and we got the glory. The success of our Apollo programme was really down to the collective effort of 400,000 members of our team of the US government and private industry. Against enormous odds, with the whole world watching, a group of engineers, scientists and managers took the risk and that team changed the way that we perceive our world. I'm proud to have played a small role in a historical accomplishment.

What are your memories of Apollo 11? What did it feel like to know that you were part of a programme that landed on the Moon?
When Apollo 11 touched down with only 17 seconds of fuel, we all started breathing again. It really was something – and, of course, Neil Armstrong's footprint on the lunar surface has gone down in history. When I mention the Apollo programme, everyone thinks of 'one small step for man, one giant leap for mankind'. That's certainly one mission for the history books.

There are other things that I remember, too. You might not know that Apollo 11 carried tubes of microfilm with it with messages from many nations of the world. After the mission, I got the chance to review those messages. One of them, which was from the Australian Prime Minister, I carried around in my pocket with me for years. He said: "The chance of dangerous adventure is available to all." What a wonderful statement. The chance of dangerous adventure means accepting the risk of failure. If you're not willing to risk failure, you don't deserve to win. But when you do win, you win big. I believe that is true in all fields of human endeavour.

Apollo 11 is a technological achievement, built by men that think and work like machines. But I don't think we were computers or robots. We were warm, feeling, committed individuals. For a time, after landing on the Moon, we felt together and confident in our abilities to do anything we set our minds to. It was an accomplishment that expanded the envelope of human experience.

> "In the next century they won't care how carefully and cautiously you survived the 21st Century"

Cunningham, along with fellow Apollo 7 astronauts Walter Schirra and Donn Eisele, participate in water egress training in the Gulf of Mexico
UNITED STATES

You mention that NASA took quite a few risks with the Apollo programme, is that still true of the agency today when it comes to spaceflight?
Today NASA has evolved into a less-efficient agency. Management today seems intent on eliminating risk and looking for absolute assurance that something could actually be done before committing to do it. Actually I believe that the American space programme is more of a reflection on today's risk-averse society. That once rambunctious spirit of innovation and adventure is being paralysed by the desire for a risk-free society. Well, I tell you this, exploration is not about eliminating risk. It's about managing risk. We're overwhelmed today with politically correct decision making. The only real limits, other than funding these endeavours, are the risks that we place on ourselves. I don't think we should be worrying about what is politically correct; we have to do what's right – even if it's unpopular.

NASA has been sliding down this hill for some time and this new attitude may have opened the door for so-called commercial space companies. NASA has always depended on private industry and most of today's commercial space companies are really government subsidised. Today, however, NASA will have far less control over the development, operations and the outcome of what's going on in private space companies. Commercial space companies explore space by the return of investment and profit margins and, believe me, the exploration of space does not satisfy either of those criteria. The financial return really comes from the commercial spinoffs, utilising the technology that was developed to make exploration possible. That's why we have many of the things that we're enjoying today because of what went on with the Apollo programme. I think it's going to be that way for the foreseeable future anyway. Safety can never be guaranteed when we explore the unknown to venture out into the unexplored frontiers, it has always been necessary that explorers should be willing to die for their efforts.

What qualities should an astronaut have?
It takes those willing to accept the challenge and who are prepared to pay the price. When we look back at the Apollo programme, we can see that it had it all: competition, challenge, imagination, leadership, teamwork, and technological breakthroughs. It also had its risk and uncertainty, its chance of dangerous adventure and it wasn't just the risk of dying – men did die in their heroic efforts. The Apollo programme advanced man's knowledge in dozens of fields of endeavour. Each mission was uncertain until splashdown. So they certainly measured up to the criteria of adventure.

What do you think will be man's next greatest adventure when it comes to space exploration?
For today's generation, the chance for dangerous adventure is the exploration of Mars. We have the resources, and the technology can be developed, but it's up to them to have the will to actually tackle this next frontier. Believe me, in the next century they won't care how carefully and cautiously you might have survived the 21st century – but they will celebrate your willingness to expand our universe and to change the way that we look at another world.

Cunningham and his crew mates were launched from Cape Canaveral, Florida, in 1968

Apollo 7 was the first manned Apollo space mission. Cunningham (right) is pictured with Command Module pilot Donn Eisele (left) and Commander Walter Schirra (middle)

© NASA

A TRIP AROUND the MOON

The Apollo 8 mission achieved a number of significant firsts for NASA and set the stage for later lunar operations

Apollo 8, the second successful manned mission of NASA's Apollo program, was originally intended as a test flight for the lunar and command/service modules that would later take American astronauts into orbit around the Moon and to the lunar surface.

However, an abrupt change in plans brought Apollo 8 to even greater significance as the crew achieved a considerable number of firsts for NASA, the Apollo program, and for mankind. Ironically, the elevated status of Apollo 8 resulted from a nudge by the rival space program of the Soviet Union. In September 1968, its Zond 5 spacecraft had carried animals into a loop around the Moon and returned safely. Rumours circulated that the Soviets intended to launch a similar manned mission before the end of the year.

Originally scheduled for early 1969, Apollo 8, the first manned space flight to originate from Florida's Kennedy Space Center, launched on 21 December 1968, following modifications to the mission. Although Apollo 8 initially included a lunar orbital flight of the command/service module and lunar module, a riskier command/service module only alteration was approved because defects in the lunar module required more time to correct, possibly jeopardising the goal of putting a man on the Moon before year-end 1969. Moving the Apollo 8 timetable forward would allow the testing of critical lunar landing procedures that would otherwise have been delayed.

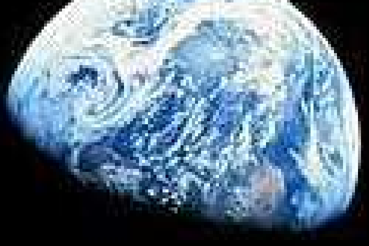
Apollo 8 launched at 7:50am. Two hours and 50 minutes later the crew received clearance for translunar injection, firing engines to point the spacecraft's trajectory toward the Moon. Just over 68 hours after liftoff, Apollo 8 reached an elliptical lunar orbit.

During their seven-day mission, the crew , consisting of Air Force Colonel Frank Borman, commander; Navy Captain James Lovell Jr, command module pilot; and Air Force Major William Anders, lunar module pilot, made history. Borman had previously set a space endurance record during the 14-day flight of Gemini 7 and served on the NASA review board investigating the fire that claimed the lives of the three Apollo 1 astronauts, while Lovell had flown with Borman on the record-setting Gemini 7 and commanded Gemini 12. Apollo 8 was Anders' first and only space flight.

The Apollo 8 crew was first to leave Earth's orbit, then orbit the Moon, returning safely. The three astronauts were the first to travel beyond a low orbit of Earth, to see Earth as a whole planet, and to directly view the dark side of the Moon. They were the first humans to escape the gravitational well of another celestial body, the Moon, and to re-enter that of Earth. Apollo 8 orbited the Moon ten times, but placing the spacecraft in its proper position was quite an achievement. The necessary engine burn had to occur at a precise time, on the dark side of the Moon, out of contact with Earth, and despite the tension this caused, it was successful.

On 24 December, the astronauts witnessed the breathtaking Earthrise above the Moon's horizon. The moment was exhilarating and somewhat unexpected. Anders seized the opportunity to snap one of the most iconic photographs of all time, and the haunting image became a symbol of environmental awareness.

During their historic Christmas flight, the Apollo 8 crew was visible to television viewers around the world during six broadcasts. A Christmas Eve



The first image of the whole Earth was taken by the astronauts aboard the Apollo 8 mission

orbiting the Moon was like a "vast, lonely, forbidding expanse of nothing." Lovell mentioned the planet Earth's "grand ovation to the vastness of space." The crew read the first ten verses of the Book of Genesis from the Bible before signing off, "Good night, good luck, a Merry Christmas and God bless all of you – all you on the good Earth."

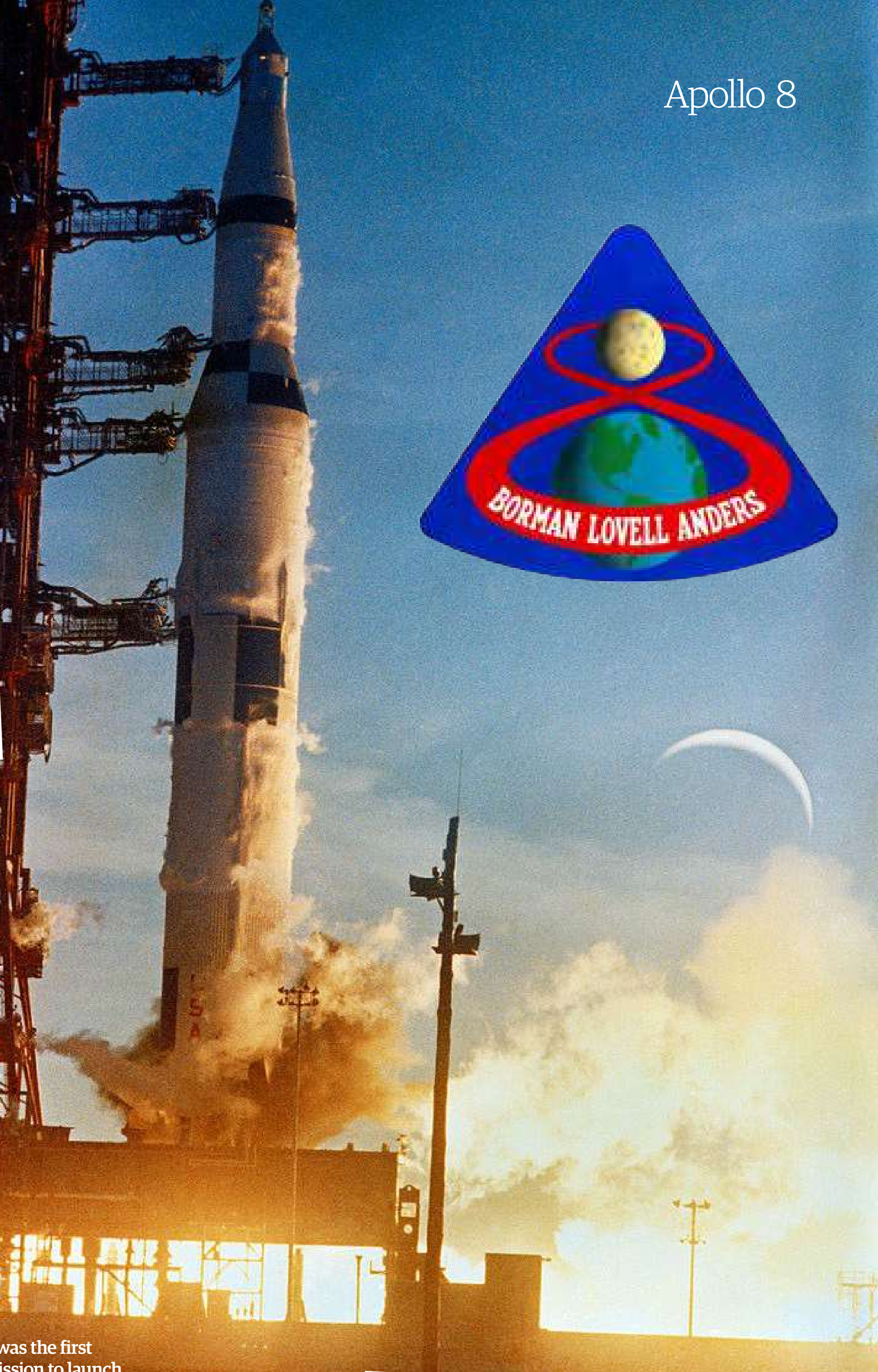
On Christmas Day, the required battery of lunar landing tests complete, Apollo 8 began its homeward trek. 'Trans-Earth Injection' had to occur at the right moment on the far side of the Moon. The procedure was executed to perfection, and when communications were restored Lovell pronounced, "Please be informed, there is a Santa Claus!" At 10:51am Eastern Standard Time on 27 December, Apollo 8 splashed down in the Pacific Ocean. By 12:20pm, the astronauts were safely aboard the aircraft carrier USS Yorktown.

The Apollo 8 mission was a resounding triumph. Yet, there had been tense moments before and during the historic flight. The Saturn V rocket had exhibited serious problems during the earlier unmanned Apollo 6 mission in the spring of 1967, including pogo oscillation – a vibration in the liquid propellant filled rocket engines caused by the instability of combustion – along with two second-stage engine failures, and a third stage that did not ignite while orbiting Earth. A manned flight was too hazardous unless these issues were corrected. Satisfactory modifications were installed and testing completed just three days before the scheduled launch. However, eighteen hours into the mission, Borman became ill with vomiting and diarrhoea. He slept for a while and declared that he felt better, but protocol required notifying mission control of the situation. To avoid breaking the news to the public, a private communication channel was used. Several hours later, after consultation with flight surgeon Chuck Berry, senior NASA officials allowed the mission to continue rather than aborting.

During the return flight, Lovell accidentally erased some computer memory while working on navigational sightings. When the crew discovered that a misalignment had occurred due to an unintentional thruster firing based on earlier data, it became necessary to manually calculate and enter the correct information. Within 25 minutes, Lovell had determined the appropriate data and performed the computer input, averting a disaster.

Sixteen months later Lovell was in command of the Apollo 13 lunar landing mission, which aborted due to an on-board explosion. He recalled that his computer-related experience aboard Apollo 8 was useful in bringing the later crew home.

The three Apollo 8 astronauts were named *Time* Magazine's Men of the Year for 1968, proof that their mission captured the public imagination.



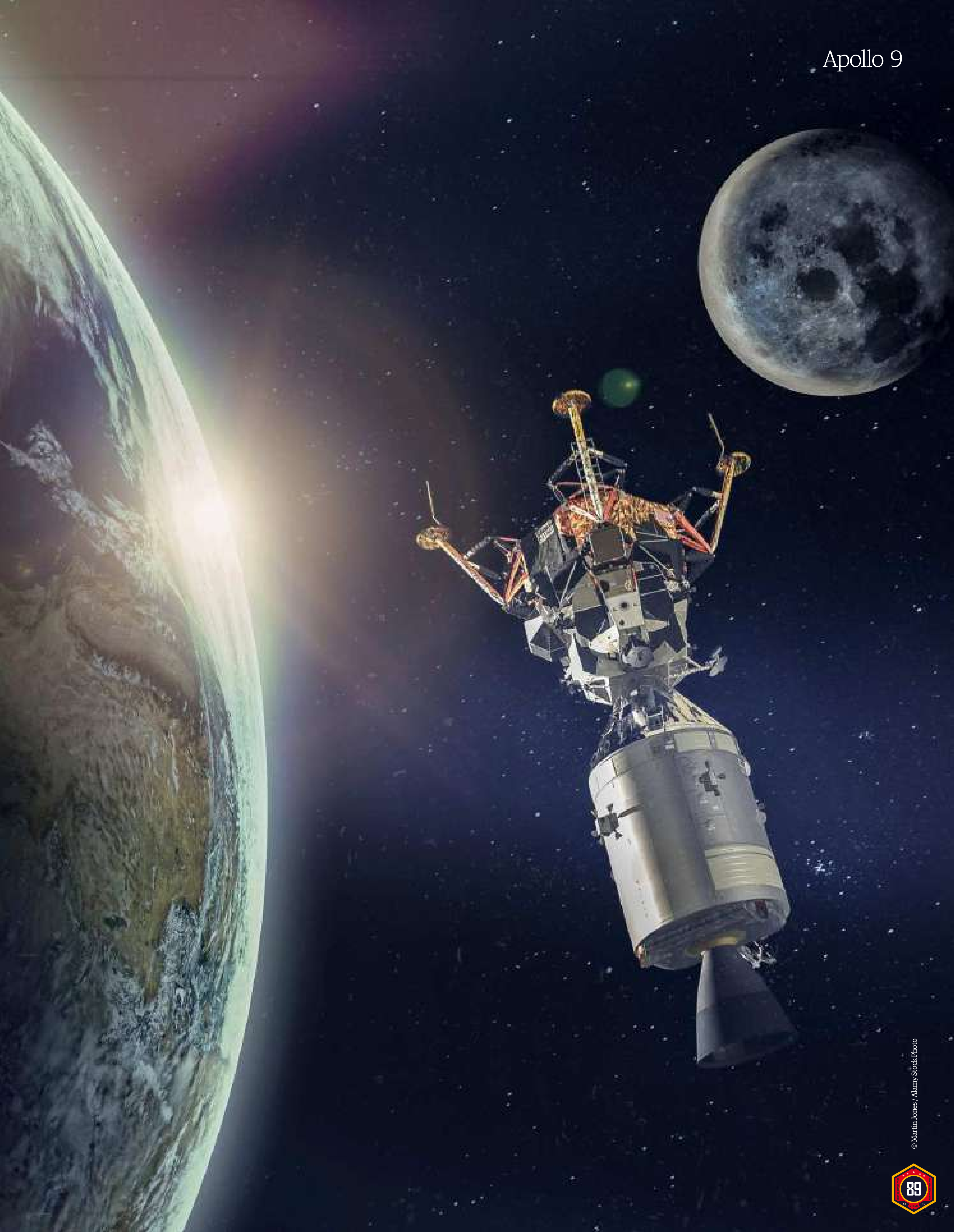
Apollo 8 was the first Apollo mission to launch aboard a Saturn V rocket, the kind that later took Apollo 11 to the Moon

© NASA

The STORY of APOLLO 9

The 50th anniversary of the Earth-orbiting mission that saw testing of vital equipment, paving the way for humankind's first step onto the Moon

★ Reported by Lee Cavendish ★



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The Apollo program paved the way for human space exploration and inspired a generation of future astronauts, scientists and engineers. Apollo 11, the mission that saw Neil Armstrong and Buzz Aldrin step foot on the Moon, wasn't possible without the ten other missions before it. Here we celebrate the 50th anniversary of the Apollo 9 mission that saw James A. McDivitt, David R. Scott and Russell "Rusty" Schweickart conduct the first tests of the crewed Lunar Module (LM) and Command Service Module (CSM) along with the portable life-support systems that would be used when exploring the Moon.

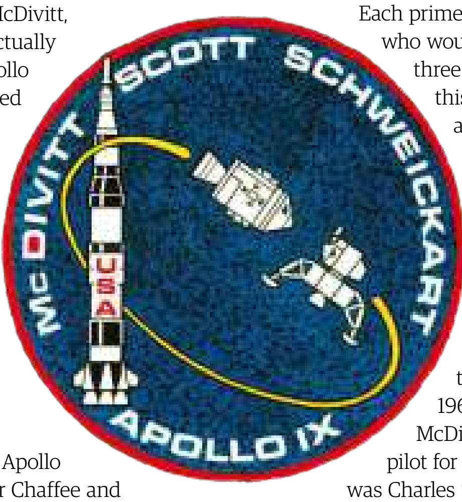
On 3 March 1969 these three astronauts strapped themselves in for the ride of their lives, sitting aboard a Saturn V rocket at NASA's John F. Kennedy Space Center in Florida, United States. This mission was only the second crewed mission to launch on a Saturn V rocket, and the third crewed mission in the United States' Apollo program. For the next 241 hours and 54 seconds the Apollo 9 crew would experience the wonders of space while performing their duties as professionals to ensure for a successful trip. But what if they weren't even supposed to be there?

This was almost the case, as McDivitt, Scott and Schweickart were all actually supposed to be on the earlier Apollo 8 mission - the mission that circled the Earth in December 1968. "Those were very complicated times and the mission shifted all over. We were actually the backup crew for the first Apollo missions, including Apollo 7, but we were also going to pick up the Lunar Module and be the first to fly it," Schweickart told us. "Then we were shifted off the backup crew and [Walter] Wally Schirra's team took our places for the first Apollo mission, with Gus Grissom, Roger Chaffee and Ed White the appointed first-choice crew. We moved into a totally different mission, but we were going to fly the Lunar Module. Then that didn't work and Frank Borman proposed moving his flight."

Each prime crew had a backup crew who would fly as the prime crew three missions later, and it was this rule that led to Armstrong and his crew flying as the prime crew on Apollo 11.

But they had to wait. As for Apollo 9, it had to reach space and test the technologies that NASA had been improving in its laboratories. Each crew member was selected from the astronaut group of either 1962 or 1963. The commander, McDivitt, had been the command pilot for Gemini 4, and his backup was Charles "Pete" Conrad Jr. The Lunar Module pilot, Schweickart, was making his first spaceflight, with his backup being Alan Bean, and Command Module pilot Scott had experience as a pilot of Gemini 8; his backup was Richard "Dick" Gordon. This backup crew served as the prime crew for the Apollo 12 mission.

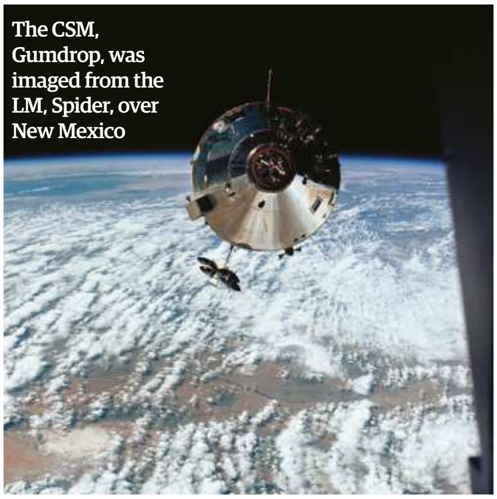
After the initial ascent it was time to test the docking between the unmanned LM, which was given the nickname Spider, still attached to the third stage of the Saturn V rocket, and the CSM module, which was given the nickname Gumdrop. During the



> *"You don't get in a suit and go outside in space if you're going to have motion sickness – that will kill you"*
> Rusty Schweickart

Rusty Schweickart was the first to test the Apollo extravehicular mobility unit

3 March 1969 saw Apollo 9 launch atop a Saturn V rocket



The CSM, Gumdrop, was imaged from the LM, Spider, over New Mexico

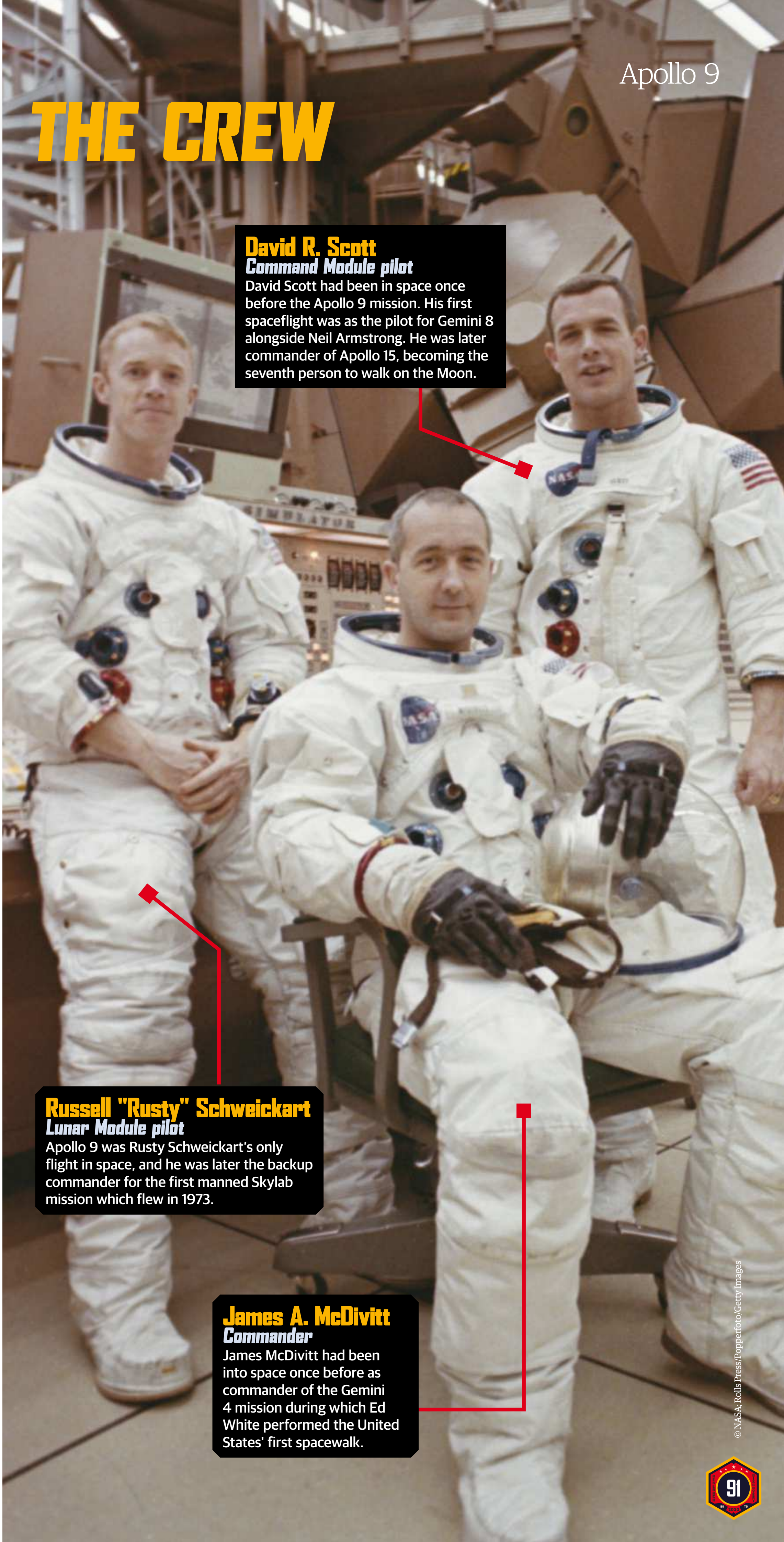
second orbit of Earth the two modules docked before jettisoning the remainder of the Saturn V rocket. This was the first hurdle to overcome before what would turn out to be an extremely fruitful ten days in space.

On the third day of flight, McDivitt and Schweickart suited up in a new-and-improved design based on the Gemini days and prepared to board Spider. During this time on board the LM they conducted systems checks and fired the module's descent rockets to simulate the throttle pattern that would be used during a lunar-landing mission. During this time Schweickart wasn't feeling too great due to the nausea he was experiencing. In fact, commander McDivitt had reported that he had vomited on two occasions.

This nausea comes from the effects of weightlessness on the organs of balance in the inner ear. With these organs not functioning properly under the effects of gravity, astronauts can become susceptible to space sickness. The Lunar Module pilot's nausea pushed back some of the crew's operations, including the first Apollo extravehicular activity (EVA). "We had to postpone the EVA because I had motion sickness the day before, and you don't get in a suit and go outside in space if you're going to have motion sickness, because that will kill you," recalls Schweickart.

This delay caused the crew to be behind schedule, so the EVAs for Schweickart and McDivitt would be restricted to just one daylight pass, and would only include the opening of the hatches of the Command Module (CM) and the LM. This wasn't a disaster, it just meant that the crew were behind a bit and restricted with their valuable time. It was the fourth flight day that saw the two venture outside the confines of the spacecraft and see the vast emptiness of space and all its beauty. The plan was that Schweickart would exit Spider, transfer to the open hatch of the CM and then return - all of which had to be done in the space of just over two hours. Schweickart once again suited up, this time wearing the new extravehicular mobility unit backpack which provided constant communication and oxygen, as well as having water circulate the suit in order to keep his body cool. After the module was depressurised and the hatch was open, the only thing keeping the Lunar Module pilot tethered to the spacecraft for just over an hour was a seven-metre (25-foot) nylon rope.

THE CREW



David R. Scott

Command Module pilot

David Scott had been in space once before the Apollo 9 mission. His first spaceflight was as the pilot for Gemini 8 alongside Neil Armstrong. He was later commander of Apollo 15, becoming the seventh person to walk on the Moon.

Russell "Rusty" Schweickart

Lunar Module pilot

Apollo 9 was Rusty Schweickart's only flight in space, and he was later the backup commander for the first manned Skylab mission which flew in 1973.

James A. McDivitt

Commander

James McDivitt had been into space once before as commander of the Gemini 4 mission during which Ed White performed the United States' first spacewalk.

© NASA; Rolls Press/Popperfoto/Getty Images

David Scott imaged inside Gumdrop

THE AIMS OF APOLLO 9

1 OVERALL CHECK OF THE LAUNCH VEHICLE AND SPACECRAFT SYSTEMS

2 FIRST FLIGHT OF THE LUNAR MODULE AND PERFORMING RENDEZVOUS AND DOCKING PROCEDURES WITH THE COMMAND SERVICE MODULE

3 TEST THE EXTRAVEHICULAR MOBILITY UNIT BACKPACK FOR FUTURE SPACEWALKS

Schweickart was imaged on his first EVA, floating outside Spider

© NASA;

Schweickart recalls his EVA fondly, saying, "I remember being way up the front of the Lunar Module with my hand on the handrail, and I just let go. With one hand I swung myself around and looked at the Earth; the Command Module was also in that direction, but mainly I could see the Earth, the black sky and the black universe above it. I just said to myself: 'This is my time to be a human, not to be an astronaut. I'm not going to think about what's next on the checklist. My job is to be a sponge, to just let this come in through the spacesuit and into me as a human being.' And that happened."

Scott also completed an EVA in this time, but was reliant on the CMS systems for life support. This spacewalk was also over the space of an hour, and in that time both the Command and Lunar Module pilots took photos of space and retrieved thermal samples from outside the spacecraft.

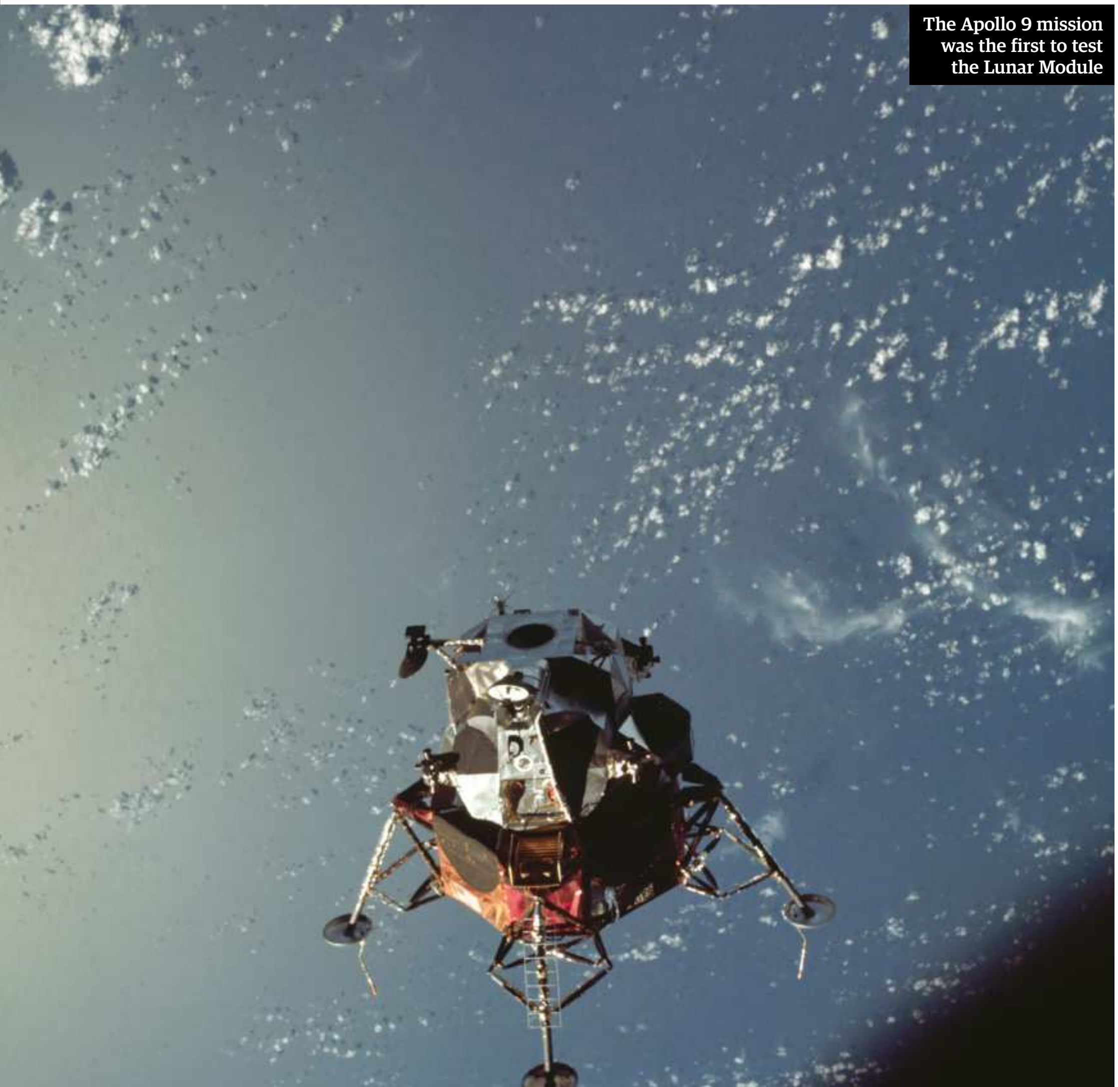
The fifth day held a new test - the crewed undocking and rendezvous of the LM and CSM. In Spider were McDivitt and Schweickart, with Scott remaining in Gumdrop. After months of simulations and training on the ground, the time had come to cut the cord and see if the LM would be capable of lowering humans down to the Moon. When undocking began, something wasn't right. "There were some very small little latches that had to release, and in the simulator on the ground, when we did the procedure everything worked well. When Dave [Scott] pushed the switch and let it go in the actual situation, the probe had not fully extended. He just hit the switch and let it go - which is what we did in the simulator on the ground - but when it reached the end of its travel pushing the Lunar Module away, those little latches, as soon as he let go, went back out, and so we went 'clunk' and stopped," says Schweickart.

> "I remember being way up the front of the Lunar Module with my hand on the handrail, and I just let go"
>
> Rusty Schweickart

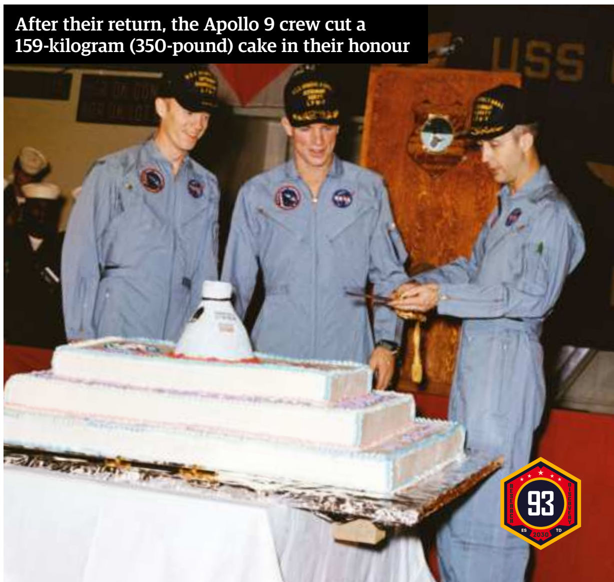
"We kind of looked at each other and wondered, 'what was that?'. McDivitt and I said we should probably redock and figure out what happened. We wanted to let the ground team work through it and figure out what happened, and then do it again. At about that time Dave looked up and saw that we weren't separated, and he just hit the switch again. As we started to drift off, we looked at each other and said: 'Well, too late now! So we'll find out when we come back from the rendezvous in eight hours if anything is wrong.'"

After the eight hours the crew had successfully redocked to the CSM, and the experience was deemed a massive success! The final four days of the mission did not include any major tests or experiments that would affect the following Apollo missions. Instead, the Apollo 9 crew conducted Earth resource and multispectral terrain photography experiments over the southern United States, Mexico, Brazil and Africa.

On 13 March 1969, the tenth day of flight that saw them complete 151 revolutions around Earth, the crew made a successful splashdown into the Atlantic Ocean - about 549 kilometres (341 miles) north of Puerto Rico. This concluded what was a massive success for the Apollo program and NASA. "The primary lesson from our experience on Apollo 9 was that everything worked well. We'd had a lot of problems in Gemini doing EVAs with a suit, and they were largely unsuccessful, but we had the brand-new suit. I had to go on the EVA, the first experience of going outside, and fortunately, nothing really dangerous happened. We also had the backpack that was going to allow us to run around on the Moon, so that was a very important test that we did in Apollo 9," concludes Schweickart.


The Apollo 9 mission was the first to test the Lunar Module

McDivitt was pictured in the lunar module, flaunting his beard growth after a few days in space


After their return, the Apollo 9 crew cut a 159-kilogram (350-pound) cake in their honour

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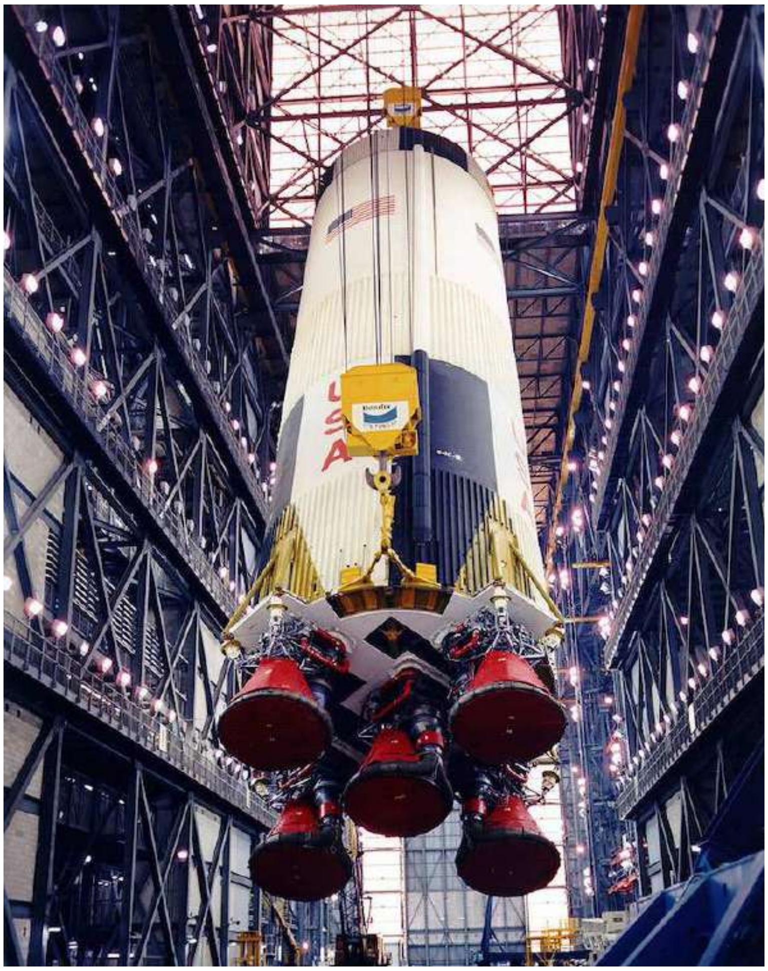
DRESS REHEARSAL for the MOON

The crew of Apollo 10 performed every aspect of an actual mission to the lunar surface except the landing itself

The fourth mission of NASA's Apollo program in the short span of seven months, Apollo 10 lifted off from the Kennedy Space Center's Launch Complex 39B on the morning of 18 May 1969. Its objective was clear - to execute every aspect of a lunar landing mission except the actual landing on the Moon.

That defining moment would, hopefully, occur weeks later with Apollo 11. However, unless Apollo 10's dress rehearsal was successful, NASA's goal, placing a man on the Moon before the end of the 1960s, would be in jeopardy.

Apollo 10 was the first lunar mission involving an entire Apollo spacecraft configured for a landing. The command/service module was a two-part vehicle, its cone-shaped command module used as a control station and crew compartment. The cylindrical service module, to the rear of the command module, contained oxygen, hydrogen, fuel, and propulsion and manoeuvre systems. The two-stage lunar module housed a lower descent stage containing the



power plant for the Moon landing. Its construction included four aluminium alloy legs for support on the lunar surface, a ladder for astronaut ingress and egress, and storage space. The descent stage also provided a launch platform for the cylindrical ascent stage, where the crewmen would work while on the Moon's surface prior to lifting off, returning to lunar orbit, and docking with the command/service module.

During the eight-day mission, Apollo 10 set the record for highest speed ever achieved by a manned vehicle at 39,897 kilometres per hour (24,791 miles per hour) while returning to Earth, and achieved the greatest distance humans have ever travelled from home, 408,950 kilometres (220,820 nautical miles) from the crew's houses and NASA mission control in Houston, Texas.

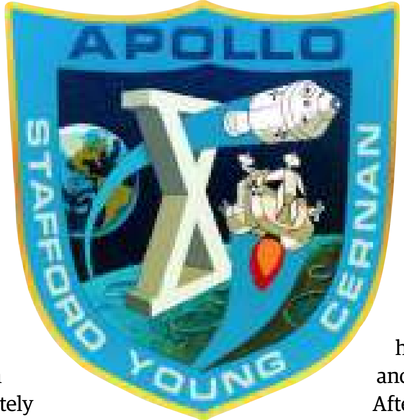
Mission commander Thomas Stafford, an Air Force officer, was a NASA veteran of Gemini 6 and Gemini 9. He was later the mission commander of the Apollo-Soyuz Test Project, a joint venture with the Soviet space program. Lunar Module pilot Eugene Cernan, a Navy officer, flew with Stafford aboard Gemini 9 and later commanded Apollo 17, becoming the eleventh man to walk on the Moon. Command Module pilot John Young, a Navy officer, had flown in Gemini 3 and Gemini 10. He later flew in Apollo 16, becoming the ninth man to walk on the Moon, and commanded two Space Shuttle missions. During Apollo 10, Young became the first person to fly solo around the Moon.

The crew nicknamed its command/service and lunar modules Charlie Brown and Snoopy after popular characters from the *Peanuts* comic strip, and cartoonist Charles Schulz created artwork for the project. The intent was to add a bit of familiarity to the Moonshot, but NASA officials considered the nicknames undignified. Nevertheless, the idea of whimsical names persisted with later Apollo missions.

Twelve television broadcasts were originally planned during the flight, the first to transmit colour images from space. The initial live transmission began three hours after launch, and the cameras provided stunning colour footage of the Earth and the surface of the Moon. By the end of the mission, 19 transmissions totalling nearly six hours had occurred, also offering viewers clear depictions of life aboard the spacecraft.

Once aloft, Apollo 10 completed one and a half revolutions around the Earth before igniting the S-IVB booster stage of its Saturn V rocket, gaining sufficient velocity to escape Earth's gravitational pull. Three days later the spacecraft reached a lunar orbit 111.12 kilometres by 314.84 kilometres (60 by 170 nautical miles) above the lunar surface.

On 22 May, Stafford and Cernan moved into the lunar module, detaching from the command/service module to execute a simulated lunar landing. They proceeded to a temporary orbit of 107.34 kilometres by 115.07 kilometres (66.7 miles by 71.5 miles). The descent engine fired for 27.4 seconds, and the lunar module manoeuvred to an orbit of 15.61 kilometres by 113.45 kilometres (9.7 miles by 70.5 miles). The astronauts then surveyed the proposed lunar landing site in the Sea of Tranquillity while their pre-landing tests were performed.



NASA officials had been concerned that Stafford and Cernan might actually go rogue and land the lunar module themselves. Cernan was later quoted as saying, "A lot of people thought about the kind of people we were: 'Don't give those guys an opportunity to land, 'cause they might!'" To eliminate the worry, the tanks in the ascent module were deliberately shorted of fuel. If the Apollo 10 astronauts had landed on the Moon, they could not have returned to the command/service module, where Young was flying alone.

While the command/service and lunar modules were separated, all three astronauts picked up an eerie whistling sound they described as "space music". Young correctly identified the source as radio interference between the two modules, but later disclosure of the event brought implausible speculation among observers that some kind of extraterrestrial communication had taken place.

This portion of the mission narrowly averted disaster when the time came to jettison the descent stage and return to the command/service module. The descent stage separated on the second attempt, and immediately the ascent stage experienced violent rolls. Cernan shouted an expletive that was broadcast worldwide as he struggled to bring the ascent stage under control. He counted eight spirals and managed to pull the vehicle out of the spin with little time to spare before a fatal impact with the lunar surface. Post-flight analysis revealed that a single switch had been in the wrong position and caused the near-catastrophe.

After reaching the proper orbit, Stafford sighted the command/service module at a distance of 77.25 kilometres (48 miles). The vehicles re-docked successfully on 23 May, and the ascent stage was jettisoned. The crew continued routine activities for the remainder of the mission.

The next day, Apollo 10 headed for home. Splashdown in the Pacific Ocean occurred on May 26, about 6.4 kilometres (4 miles) from the recovery ship, the aircraft carrier USS Princeton. The pathway to the Moon was thoroughly charted.

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NASA's FORGOTTEN GENIUSES

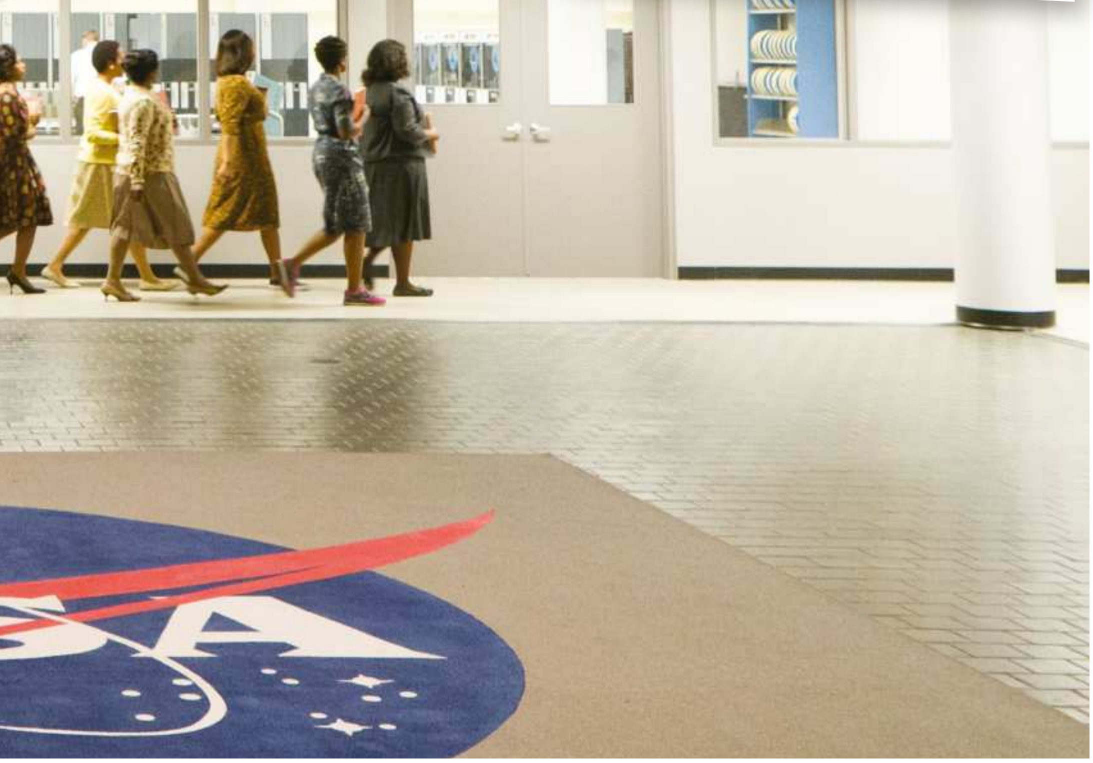
How 'female computers' helped the USA reach for the stars and beat the Soviet Union to the Moon

Written by Jonny O'Callaghan

Hidden Figures tells the story of NASA's 'women computers'

Dorothy Vaughan (far left), pictured with two other computers at NACA

Katherine Johnson, pictured at NASA in 1966



When Katherine Johnson left university in 1937, her career options were limited. Despite being an extremely gifted mathematician, she was a woman and an African American, two qualities that made her quite unemployable in a discriminatory society. So she became a teacher, one of the few professions she could enter. Two decades later, however, she found herself at the centre of the Space Race between the world's two superpowers. Ultimately, her talents – and those of many other women like her – helped send humans to the Moon.

In a time before women's suffrage, and before the civil rights movement gave African Americans a voice, women like Johnson faced not only discrimination but also segregation in the workplace. The state of Virginia, in particular, was fiercely intolerant to African Americans in the early 1900s, and one of the least progressive states in the nation. Although the Nineteenth Amendment to the US Constitution had been passed by Congress in 1919, giving women the right to vote, the Virginia General Assembly delayed its ratification until 1952. By that point, women had been voting and even holding public office for more than 30 years.

At the Langley Research Centre (LaRC) in Virginia, however, things were different. The nation's first aeronautics laboratory was established in 1917 and would go on to become the birthplace of the US space programme in the 1950s. It would be here that the original NASA astronauts would undertake their training, and where African-American women like Johnson would help launch man into orbit. The LaRC represented an island of rationality within the state of Virginia, where forward thinking was not only allowed and encouraged, but essential.

A consequence was that the LaRC operated in defiance of Virginia laws, and that included policies towards women and African Americans. In the 1930s, with only a few hundred engineers on its books and needing extra resources, the National Advisory Committee for Aeronautics (NACA) – which would become NASA in 1958 – started hiring women to sift through data and perform calculations. Using so-called 'women computers' was not unprecedented; in the field of astronomy, the practice had been carried out for decades, and had led to some ground-breaking research. Notably, in 1912, an astronomer called Henrietta Swan Leavitt at Harvard had found that certain types of pulsating stars could be used as distance markers in the universe. Her amazing discovery ultimately led to the revelation that our galaxy is not alone in the cosmos.

At the LaRC, this programme benefited both parties. For the centre itself, women became a key part of the organisation, measuring and calculating the results of wind-tunnel tests. A memo dated 1942 stated: "The engineers admit themselves that the girl computers do the work more rapidly and accurately than they would." For the women involved, it was welcome work that was more financially rewarding than other professions, such as teaching. The first female to break the gender barrier was Pearl Young, who was hired to work at the LaRC in 1922 as a physicist. Later, she would play a vital role in making the work carried out by NACA more accessible to the public, in the form of readable technical reports, and go on to become chief technical editor.

When World War II struck and able-bodied men were summoned to fight, Langley began hiring black female mathematicians, too. President Roosevelt played a big part in this, as his issuing of Executive Order 8802 prohibited racial, religious and ethnic discrimination in the country's defence industry. Due to segregation laws, however, the new recruits were kept separate from their white female counterparts and assigned to the 'West Area Computers' unit. At its peak, it's thought there were about 200 women doing computing work for NACA, about 70 of who were African American. The centre was so impressed by these workers that, after the war ended, they continued to employee women computers.

In the 1950s, the LaRC found itself becoming involved in rocket research, as the Space Race between Cold War rivals the US and the Soviet Union began. Langley's research took on a whole new meaning - they would be helping to send Americans to space in the bid for supremacy. The research was slow and steady at first, until 4 October 1957. That was the day the Soviet Union made history and launched the world's first artificial satellite, Sputnik 1, into orbit. Spurred on by the challenge, NACA was re-purposed into the National Aeronautics and Space Administration (NASA) and the race was on.

Three remarkable African-American women were working at the LaRC during this time, and their achievements are finally getting the recognition

> "Due to segregation laws, however, the new recruits were kept separate from their white female counterparts"

The first American to orbit Earth, John Glenn, launches on Friendship 7 on 20 February 1962

Melba Roy, a female computer at NASA in 1964

THE HISTORY OF 'FEMALE COMPUTERS'

Before modern electronic computers, the term denoted someone who computed something, and was used as far back as the 17th century. The work was often tedious, generally sifting through data and performing calculations, and it was generally carried out by men. In the late-19th century, however, astronomer Edward Charles Pickering at Harvard began employing women for the roles, dubbed 'Pickering's Harem'. This undoubtedly reflected the status of women at the time and they were paid half of what the men were, and yet they helped to map the universe.

The positive effect was that many agencies – including NASA – started employing female mathematicians to perform this type of work. Although not wholly prestigious, it provided a welcome career path for women in the early-20th century. Many went on to be programmers or engineers with the advent or electronic computers. During World War II, with a drastic shortage of manpower, the practice was greatly expanded. It opened doors for a huge number of people.

Grace Hopper, for example, is generally regarded as one of the first computer programmers ever in 1944, and was posthumously awarded the Presidential Medal of Freedom by President Obama on 22 November 2016, along with Margaret Hamilton, a computer scientist who played a key role in landing humans on the Moon. Katherine Johnson, one of the three main characters in *Hidden Figures*, also received the award in 2015.

President Barack Obama presents Katherine Johnson with the Presidential Medal of Freedom

A group of computers (front row) at NACA in the 1950s. Mary Jackson is on the far right

they deserve in the biographical blockbuster *Hidden Figures*. While only one was directly involved in sending people to space, each had their part to play in making the agency the world leader in space exploration, and changing attitudes there for good.

Dorothy Vaughan was hired by NACA in 1943, and it quickly became apparent that she was a very capable manager of people and a good judge of skill. When a white woman in charge of the West Area Computers became sick, Vaughan stepped in as acting head, and ended up in the role for three years - held in limbo - before being given the job officially. "Dorothy was the first black woman supervisor for NACA and NASA, and she was exceptional in a wide number of things, such as a sense of justice and willingness to go that extra step," said Bill Barry, NASA's Chief Historian and a consultant on the *Hidden Figures* film. Vaughan would often put her own position on the line in order to protect her team.

Mary Jackson, who came in to the LaRC as a computer, also had a degree in maths and physics, and was very mechanically inclined. She would end up becoming the first black female engineer and, Barry said, possibly the first female engineer in the whole agency. "That was pretty exceptional at the time," he added.

But perhaps the most outstanding of the three was Katherine Johnson, at least in terms of her "raw intellectual ability," according to Barry. She had a mind wrapped around numbers, and could see things others couldn't. "I counted everything," she once said, "The steps to the road, the steps up to the church, the number of dishes and silverware I washed… anything that could be counted, I did." On her lunch breaks, she would pour over space technology manuals to figure out what her superiors were doing, and how her work fit in.

A pivotal moment in the women's lives was the sending of astronaut John Glenn into space. On 12 April 1961, the Soviet Union and Yuri Gagarin shocked the world by beating the USA to putting a man in to orbit. He was followed three weeks later by American Alan Shepard as part of Project Mercury on 5 May 1961, but the Americans were playing catch-up, and they knew it. First after first was going to the Soviets, and they looked ever more likely to send a human to the Moon - the arbitrary 'end goal' of the Space Race.

Shepard's flight was suborbital, meaning that his spacecraft had entered space and returned to Earth without entering orbit, whereas Gagarin's had been orbital. After another American suborbital flight, made by Gus Grissom, the aim was to send Glenn on an orbital flight in 1962 and match the Soviets. This was where Katherine Johnson came in. She was the expert on calculating the geometry of trajectories, namely how you got from one place

From left to right, Vaughan, Johnson and Jackson in *Hidden Figures*

Katherine Johnson in *Hidden Figures*, played by Taraji P Henson to another in space by firing retro-rockets. She had done these calculations for Shepard's flight, but they were getting more and more complex, leading NASA to start using actual mechanical computers. However, they weren't considered reliable, and the software wasn't as robust as it needed to be.

"When it was time for Glenn's flight, the critical question was whether the computers worked and gave the answers they wanted," Barry explained. Glenn's solution? "Get the girl to check the numbers." It was now up to Johnson to manually work out the computer's calculations, and make sure they were correct. It took Johnson a day and a half to plough through the millions of calculations. In the end, her data matched the computers, and the mission went ahead. Glenn's flight was a success and, eight years later, men - Americans - would walk on the Moon, winning the Space Race.

> "She was the expert on calculating the geometry of trajectories, namely how you got from one place to another in space"

A human computer at work with a microscope, collecting data at Langley Research Center

Johnson's work proved crucial to later Apollo missions too, including solving issues with the rendezvous and docking techniques required to link two spacecraft. This would be crucial to getting the men on the Moon back to Earth - by docking their lunar module with the command module in orbit. "If you ask her, she'll tell you that's her most important work, making sure those calculations happened so they could rendezvous in lunar orbit," said Barry. Johnson's work even provided the backbone of modern spaceflight, as much of the maths used today can be traced back to her. She also wrote a technical report on the subject, with the somewhat unwieldy title of 'Determination Of Azimuth Angle For Placing A Satellite Over A Selected Earth Position'.

Perhaps one of the most remarkable things about all this, though, is just how much of a microcosm the LaRC was. Inside, the women were allowed to chat freely, regardless of race. Outside, they weren't even allowed to sit and talk to each other in a restaurant. Barry told of a story of a NASA engineer in downtown Hampton, Virginia, one night in the late 1950s, who saw people harassing an African-American man who worked at Langley. The engineer went over to intervene, and found himself thrown in jail. "I think that tells you something about the environment there," added Barry.

These three women have been overlooked until now, but the impacts made by these early NASA pioneers were far reaching. Mary Jackson, later in her career, for example, used her mathematical skills to show there was a bias against promoting women. She helped other women advance their careers, and ultimately became the federal women's programme manager at Langley. Now we live in an era when NASA has been directed by an African-American man, Administrator Charles Bolden, and a woman, Deputy Administrator Dava Newman, and it's commonplace for women to lead technical projects at NASA in Langley. The LaRC serves as a reminder that, in sometimes the most unexpected places, rationality can prevail. "They were a group of engineers, not used to fitting in, and they found each other," said Barry. "I think it shows humanity at its best. It shows what we can be like when we act like decent human beings."

FIVE KEY NASA WOMEN

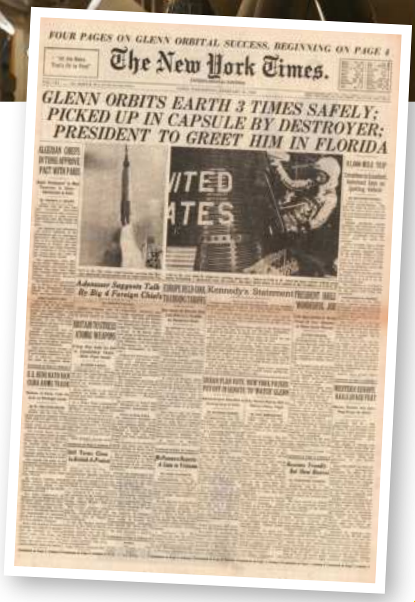
Margaret Hamilton
Margaret Hamilton was a computer scientist working with NASA in the 1960s, leading the team that developed the software for Apollo and Skylab. She was awarded the Presidential Medal of Freedom in 2016 for her work.

Sally Ride
Trailblazer Dr Sally Ride was the first American woman to go to space, aboard Space Shuttle Challenger in 1983, and she flew again in 1984. She was completing her PhD in physics when she discovered that, for the first time, women could apply to become astronauts.

Kalpana Chawla
In 1997, Kalpana made history by becoming the first Indian-American to go to space, aboard Space Shuttle Columbia. She flew again on Columbia in 2003, but died tragically, along with her crewmembers, when the shuttle broke up on re-entry.

Astronaut John Glenn, the first American in space, entering his spacecraft Friendship 7 prior to launch, 1962

Katherine Johnson worked on calculating trajectories, launch windows and return paths for spacecraft at NASA



FOUR PAGES ON GLENN ORBITAL SUCCESS, BEGINNING ON PAGE 4

The New York Times.

GLENN ORBITS EARTH 3 TIMES SAFELY; PICKED UP IN CAPSULE BY DESTROYER; PRESIDENT TO GREET HIM IN FLORIDA

Adenauer Suggests Talk By Big 4 Foreign Chiefs

Kennedy's Statement

Shana Dale

In 2005, Shana Dale became the first female deputy administrator of NASA. She held the position until 2009, and has been succeeded by two more women – Lori Garver and Dava Newman. At the time of writing, no woman has yet become NASA administrator.

Peggy Whitson

The American biochemistry researcher became the first woman to command the ISS in 2007. She has been to space three times, including most recently on Expedition 50 and 51, and is NASA's most experienced female astronaut.

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INSIDE APOLLO 11

THE MOON, 16-24 JULY 1969

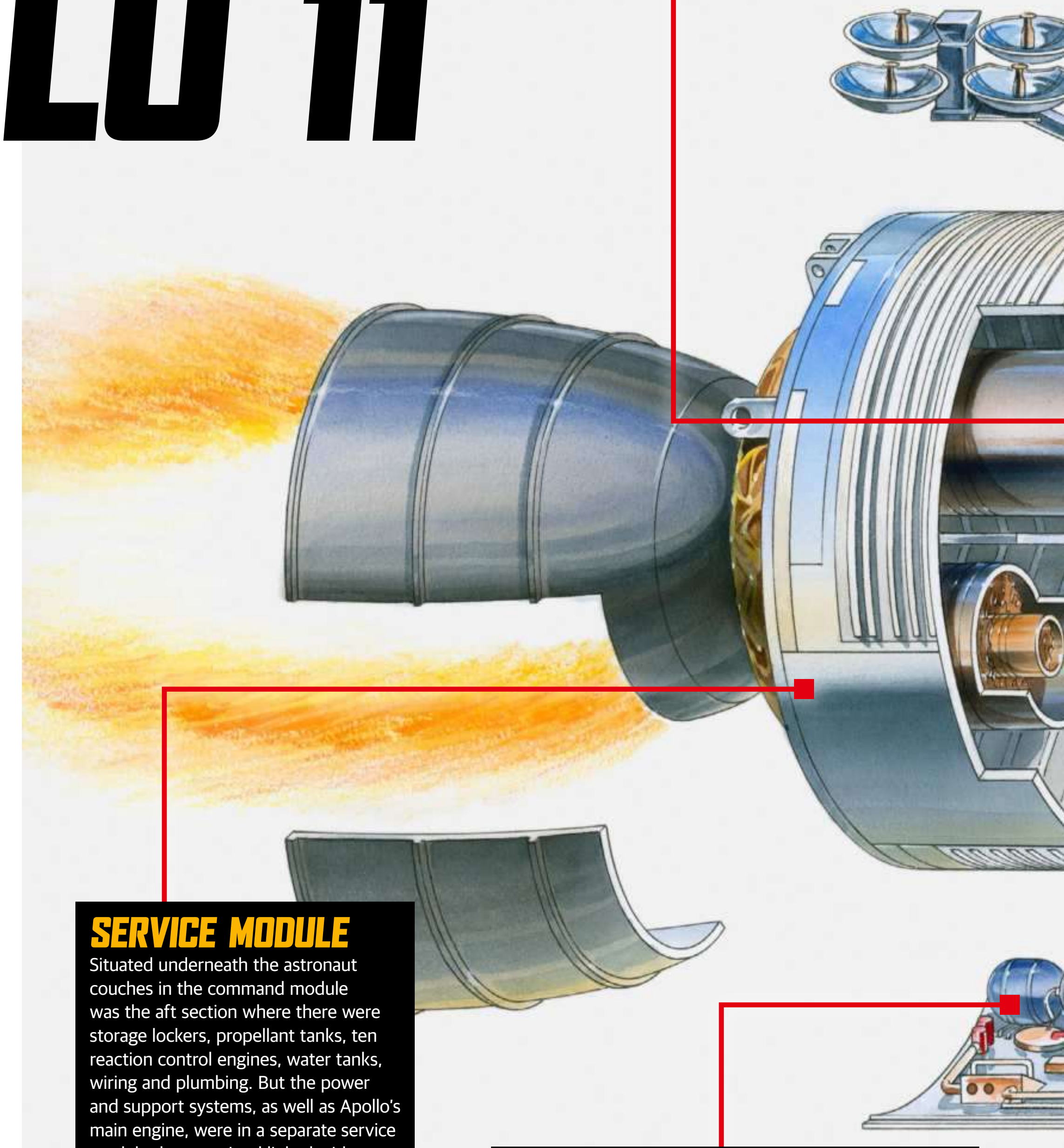
The space race – a high stakes battle between the United States of America and the Soviet Union to explore and conquer the night sky – sparked into life on 4 October 1957. The USSR had launched the first satellite, Sputnik 1, into orbit around the Earth, taking the Americans by surprise. The USA felt it had to respond.

The National Aeronautics and Space Administration (NASA) formed on 29 July 1958, vowing to peacefully explore space for the purposes of science. But when the Soviets made Yuri Gagarin the first human in space on 12 April 1961, the USA became determined to put a man on the moon. President John F Kennedy said he wanted to see this happen by the end of the decade so the three-man Apollo program was given the go-ahead in 1961. Over the course of the next few years, the Americans came just short of landing. In 1969, however, Apollo 11 was the victory.

The Apollo spacecraft was powered skywards on the nose cone of the Saturn V, which remained the world's most powerful rocket until the debut of Space X's Falcon Heavy last year. The launch was watched by a million people at Kennedy Space Center, Florida. At 110.6 metres (363 feet) high, the rocket comprised three stages. The first had five engines that burned 15 tonnes of fuel per second during the launch from Earth, the second helped lift Apollo into space, and the third broke away from the rest and used a single engine to force Apollo to leave Earth's orbit.

While this was taking place, astronauts Neil Armstrong, Buzz Aldrin and Michael Collins were safely inside Apollo's command module. As they got within distance of the moon, Armstrong and Aldrin entered the lunar module, Eagle, touched down on the our natural satellite's surface and began exploring for 21.5 hours.

The spacecraft doubled as transport, an office and accommodation, protecting those on board from the hostile environment of space while ensuring everything they needed was on hand. No-one has touched down on the moon again since 11 December 1972.



SEATING ARRANGEMENTS

Manufactured by North American Rockwell, Apollo 11's Command Module was called Columbia and it carried astronauts Neil Armstrong, Edwin "Buzz" Aldrin and Michael Collins to the moon and back. Doubling as the control centre and living quarters, the cramped space had three couched seats capable of adjusting from flat to 85 degrees. For the launch journey, Armstrong sat to the left looking out, Aldrin in the middle and Collins to the right. Collins and Aldrin switched places for the landing.

SERVICE MODULE

Situated underneath the astronaut couches in the command module was the aft section where there were storage lockers, propellant tanks, ten reaction control engines, water tanks, wiring and plumbing. But the power and support systems, as well as Apollo's main engine, were in a separate service module that remained linked with the command module (forming the Command and Service Module). These modules remained together during the trip to the moon and while the craft was in lunar orbit, being jettisoned only on the return trip to Earth.

HEAT SHIELD

Given that the temperature on the surface of the command module reached as high as 2,760 degrees Celsius (5,000 degrees Fahrenheit) during its descent, it was vitally important to protect the crew from being cooked. NASA's engineers, who had worked on the Apollo program since 1961, devised a heat shield that used an ablative coating. As temperatures rose, the coating eroded and the excessive heat was simply reflected away.

CRAMPED CONDITIONS

The astronauts remained seated for most of the 400,000km (250,000 mile) trip since the command module was just 12 feet 10 inches in diameter and 10 feet 7 inches tall. The only way two astronauts could stand at the same time was to fold the seat portion of the centre couch but even then, of the interior volume's 366 cubic feet, only 210 cubic feet was usable given the amount taken up by equipment bays, lockers, astronauts and couches.

STORAGE OF VITAL ITEMS

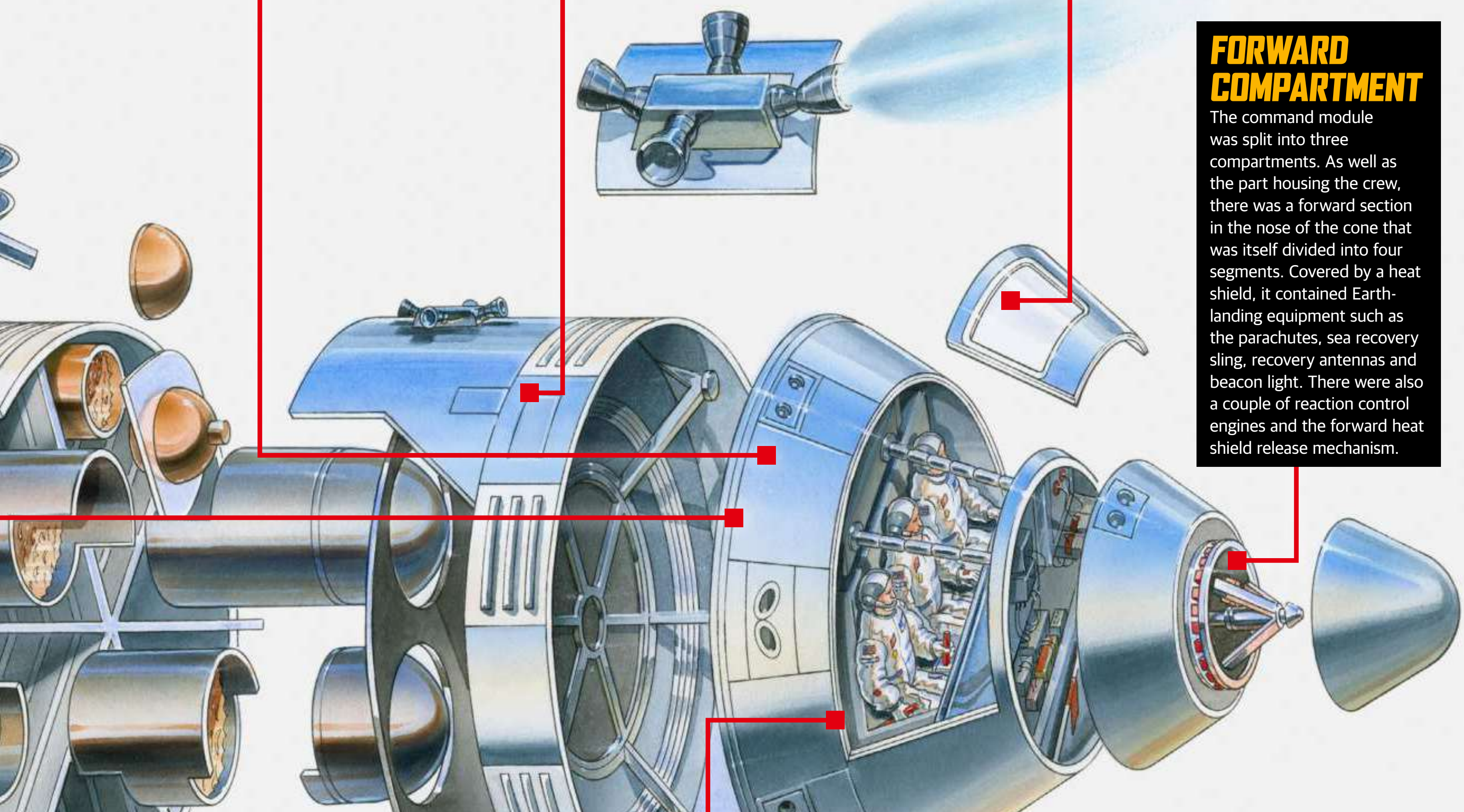
Lining bays on the interior walls of the spacecraft was lots of equipment such as emergency medical kits, sanitation supplies, waste management, water, clothing and food (the first meal they ate was beef, potatoes and grape juice). Michael Collins also drew a small calendar on a section of smooth wall underneath one of the lockers. The dates 16 to 23 July 1969 were crossed out, leaving just 24 – the day of the landing.

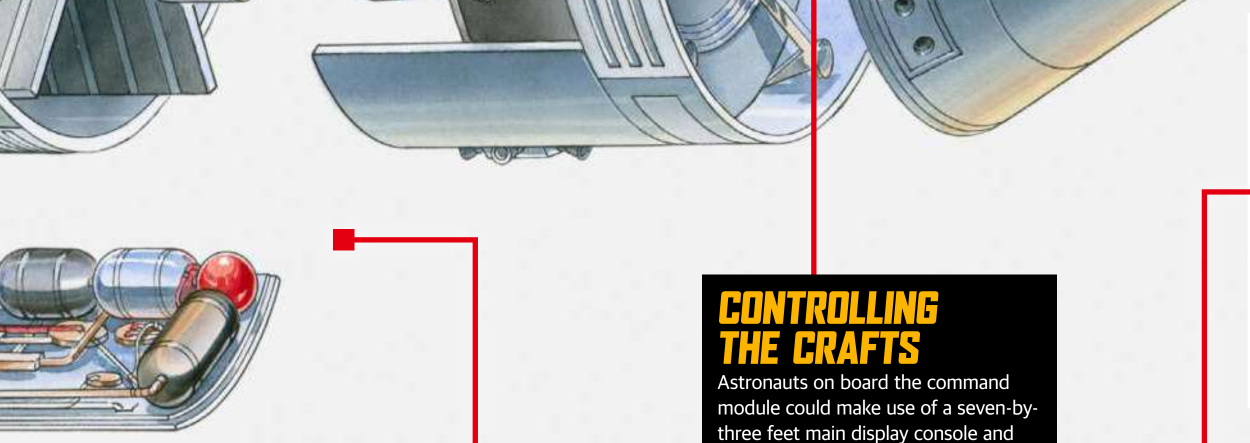
AMAZING VIEWS

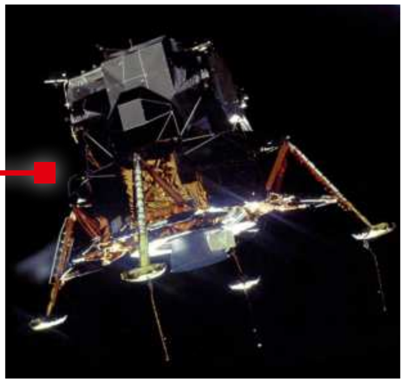
The astronauts could gaze at the stars with five windows to look out of. As well as two forward-facing rendezvous windows measuring 200 by 330 milimetres (8 by 13 inches), there were two of 330mm (13 inches) square on either side of the outer seats and a circular one, 27 cm (10 5/8 inches) in diameter within the access hatch. Three thick panes of glass were placed within each opening.

FORWARD COMPARTMENT

The command module was split into three compartments. As well as the part housing the crew, there was a forward section in the nose of the cone that was itself divided into four segments. Covered by a heat shield, it contained Earth-landing equipment such as the parachutes, sea recovery sling, recovery antennas and beacon light. There were also a couple of reaction control engines and the forward heat shield release mechanism.







GETTING IN AND OUT

The astronauts climbed aboard the command module via one of two side hatches. But there was also a third hatch mounted at the top of the docking tunnel. After leaving Earth's orbit, the command and service module separated from the rocket, turned and docked with the lunar module. This third hatch allowed astronauts to make their way into the lunar module. This would land on the moon and become their home as they explored the lunar surface.

CONTROLLING THE CRAFTS

Astronauts on board the command module could make use of a seven-by-three feet main display console and its accompanying wings, managing communications, fuel, the electrics and other functions via toggle and push switches. The ascent stage of the lunar module was less sophisticated but it had instrument panels and flight controls along with its own hypergolic propellant tanks to return it back to the command and service module.

LUNAR MODULE

While Collins stayed on the command module, two of the three astronauts – Armstrong and Aldrin – entered the lunar module. Devised in two parts – with ascent and descent stages – it landed on the moon on four splayed, shock-absorbing legs and the astronauts went outside by climbing through a hatch and down a set of ladders. The astronauts had to stand to control the vehicle and they were able to communicate with mission control via antenna.

© DK Images

"ONE SMALL STEP for MAN..."

Inside the personal journey of Neil Armstrong, from flying ace to first man on the Moon

Written by Dr Gemma Lavender

Neil Armstrong was going down. Long before Apollo 11 entered the history books, Armstrong was a US Navy fighter pilot, serving in the Korean War. Just 21 years old, he was youngest officer in the VF-51 Screaming Eagles all-jet squadron. On his first mission, his Grumman F9F-2B Panther was strafed by anti-aircraft fire as he carried out a low-altitude bombing at 350 mph (560 km/h). As he struggled to get his plane under control, his right wing clipped a pole just metres above the ground, ripping a part of it clean off. Showing the nerves of steel that would define his illustrious career, Armstrong somehow managed to fly his almost-wrecked jet back to safe territory before ejecting.

Born on 5 August 1930, in the small town of Wapakoneta, Ohio, Armstrong fell in love with airplanes at a young age. He took his first flight with his father, Stephen, at the age of six, before getting his pilot's licence as a teen. However, aeronautical engineering was his real passion - understanding how planes fly, and how to make them fly better. He studied at Purdue University in Indiana, before being called up to the US Navy.

Three years, 78 combat missions, 121 hours in the air and five medals later, Armstrong retired from active service, completed his university degree, and began a new career as a test flight pilot. Armstrong was sent to the famous Edwards Air Force Base in California. Home to the High-Speed Flight Station, this was operated by the National Advisory Committee for Aeronautics (NACA), the precursor to NASA. This desert base was where flying ace Chuck Yeager first broke the sound barrier in 1947, and the cutting-edge in aeronautics were developed. However, a test pilot's life was never easy. On 22 March 1956, Armstrong was tasked with flying a modified B-29 Superfortress, which was to deploy a smaller Skyrocket plane in midair. But at 30,000 feet, one of the B-29's four engines stopped working.

To maintain an airspeed suitable for deploying the Skyrocket, Armstrong and his co-pilot Stan Butchart had to enter a dive. As the Skyrocket successfully blasted off, one of the blades from the broken engine's propellor flew off and took out two of the B-29's other engines. Miraculously, Armstrong still managed to land the 33,800 kg bomber with just the one remaining engine.

> "Aeronautical engineering was his real passion – understanding how planes fly, and how to make them fly better"

Armstrong was involved in numerous other dangerous incidents. One of his fellow test pilots, William J 'Pete' Knight, who came up through the Air Force, attributed this to 'pilot-engineers' such as Armstrong tending to fly in a more mechanical and less instinctive fashion. However, others thought Armstrong's ability to survive these disasters proved he was one of the best test pilots in the business.

Certainly NASA - as it was called by 1958 - thought so. But they still had a requirement that you had to be a military test pilot to become a NASA astronaut. Since he had left the navy, Armstrong was now a civilian. He was therefore ineligible to be part of the 'Mercury 7' team, which headed up the United State's first space mission. However, in 1962, everything changed for Armstrong, for better and for worse.

Armstrong had married his first wife, Janet, in 1956 and together they had three children - Eric, Karen and Mark. However, tragedy struck when two-year-old Karen, who her father affectionately nicknamed 'Muffy', was discovered to have a malignant tumour in the middle part of her brain stem. The radiation and cobalt therapy treatment was too much for the little girl, and terribly weakened by the illness and the attempts to cure it, she caught pneumonia and died in January 1962.

Although grieving, Armstrong used his work as a way of dealing with the pain of losing his daughter.

It was all the more poignant then when, in September of that year, Armstrong was announced in the next batch of astronauts as NASA changed their policy on civilians. 'The New Nine' as the astronauts were termed, were among the best astronauts that NASA have ever had. Indeed, many of them went on to fly Apollo missions to the Moon, including Jim Lovell, Pete Conrad, and John Young, but even in

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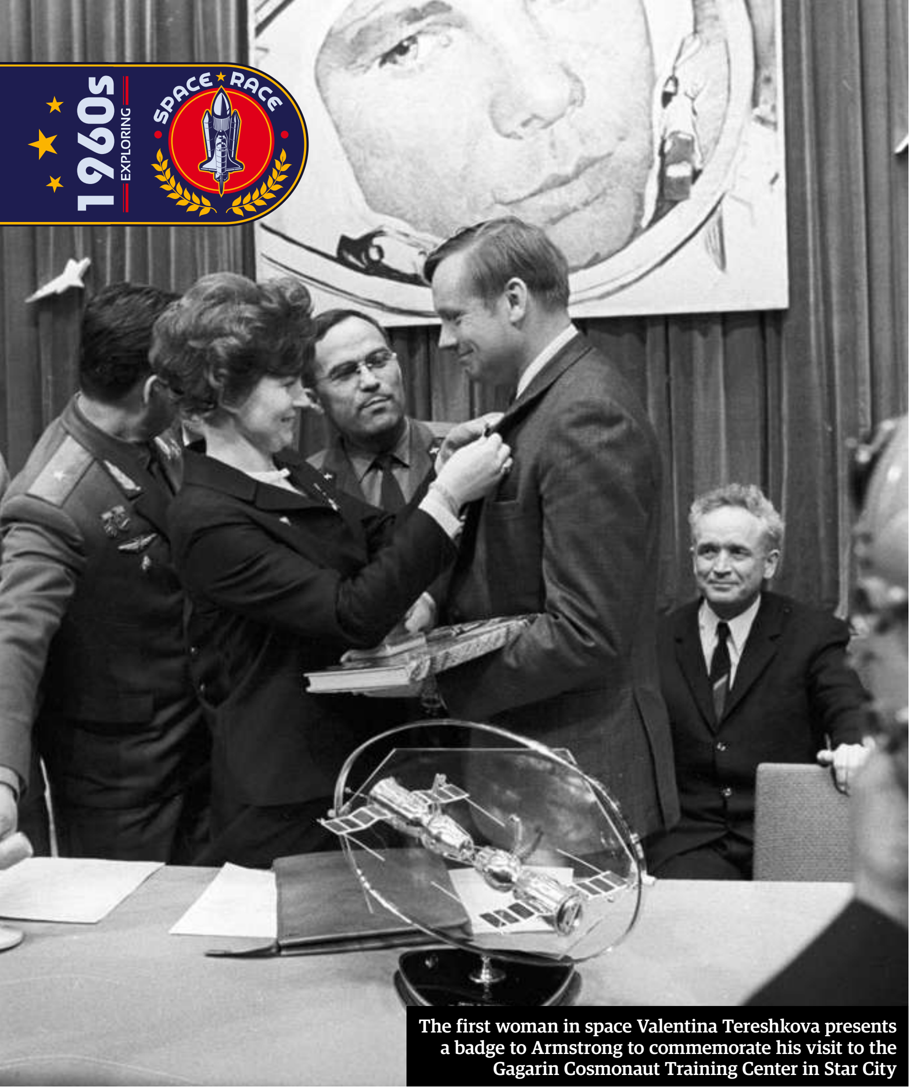
Neil Armstrong (left) flies an F9F-2 Panther over Korea

NASA
ARMSTRONG



The first woman in space Valentina Tereshkova presents a badge to Armstrong to commemorate his visit to the Gagarin Cosmonaut Training Center in Star City

Armstrong stands next to the X-15 after he carried out a research flight on 30 November 1960

1962 it was recognised that Armstrong was the best of the best.

Following President John F Kennedy's declaration to send astronauts to the Moon by the end of the 1960s, training for the New Nine began in earnest. Their first space missions were to be part of Project Gemini, which was a series of missions into Earth's orbit aboard the tiny two-man Gemini capsules. Initially selected as back-up to Gordon Cooper on Gemini 5, his first voyage into space was as commander of Gemini 8, with fellow astronaut Dave Scott flying beside him as co-pilot.

Gemini 8 was perhaps the most ambitious spaceflight to have been attempted by that time. Armstrong and Scott's mission brief was to get into orbit, perform the first ever rendezvous and docking with an unmanned vehicle, make a number of manoeuvres and also send Scott out on a spacewalk before returning to Earth. In a terrifying twist, however, after performing the docking, the two spacecraft began to roll out of control.

Armstrong switched to the Gemini capsule's Orbital Attitude and Manoeuvring System, or OAMS, which is a system of thrusters used to control spacecraft attitude to counteract the roll, but it didn't work. The Gemini capsule undocked, but this only served to increase its roll to one rotation per second, forcing Armstrong to apply the Reentry Control System to counteract the spin. However, the rules said that once the Reentry Control System is switched on, the mission must end early and return to Earth.

It was later determined that a short circuit in the wiring had prevented one of the thrusters switching off. Armstrong and Scott received the NASA Exceptional Service Medal for their calm response to the crisis, and NASA learned a great deal about how to rendezvous and control two spacecraft that have docked together – a crucial learning experience ahead of the Apollo missions which would see multiple rendezvous and dockings. Indeed, the entire Gemini program was to prepare for Apollo. Armstrong was given command of Apollo 11, with Michael Collins as Command Module pilot and Buzz Aldrin as the Lunar Module pilot. However, flying in space was one thing, but landing a spacecraft on the Moon and then taking off again was a completely different kettle of fish for the team.

> "The next stop was a region on the surface in the Sea of Tranquility"

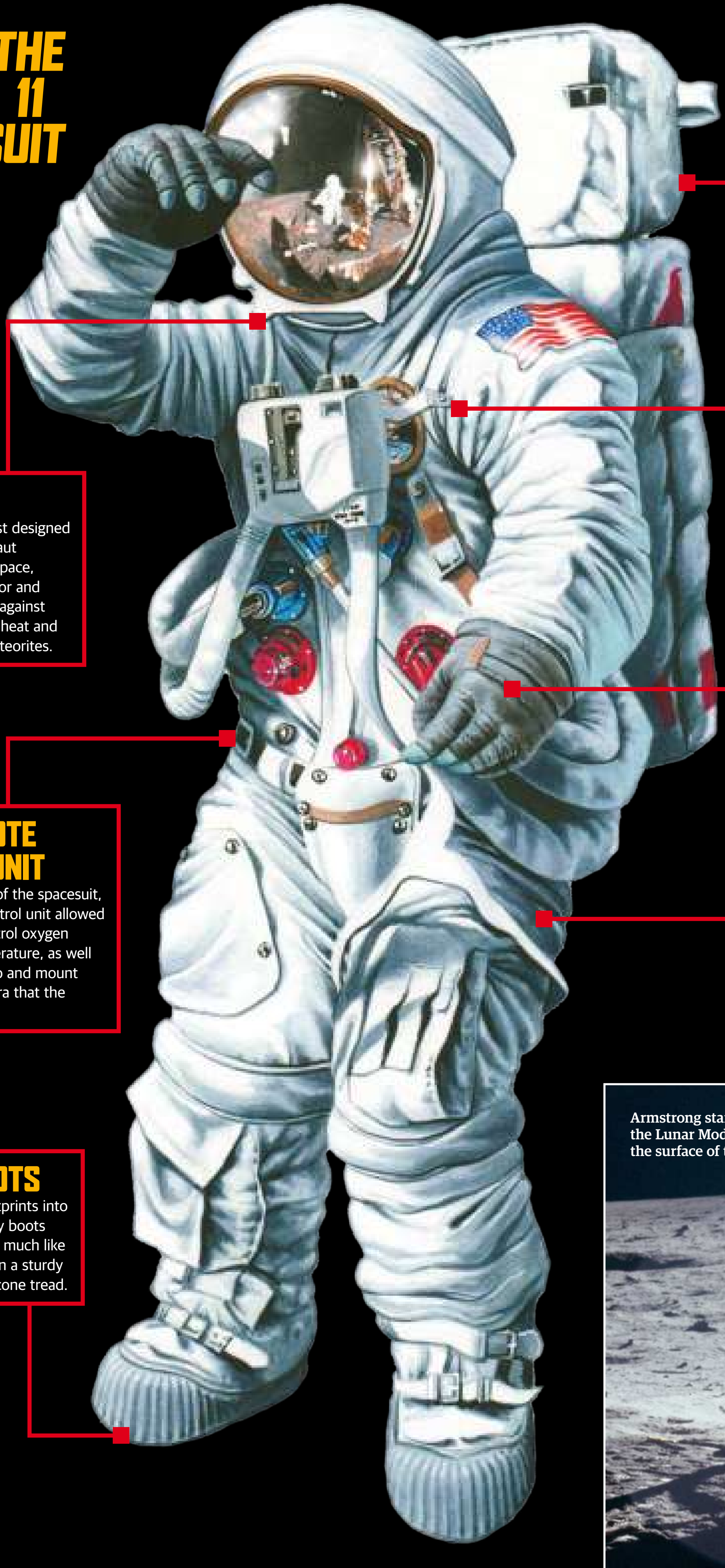
To train, the astronauts were given the flying bedsteads. This was the nickname for the Lunar Landing Research Vehicles (LLRVs) and their successor, the Lunar Landing Training Vehicle (LLTVs), which were skeletal contraptions with rocket thrusters strapped to them and literally a jet engine blowing upwards to counteract five-sixths of the LLRV's weight to simulate the one-sixth Earth gravity on the Moon. While flying an LLTV, Armstrong experienced yet another of his dramatic near misses, once again displaying calmness in the face of danger. On 6 May 1968, Armstrong's LLTV went out of control, forcing the Apollo astronaut to eject moments before the LLTV plummeted to the ground and exploded on impact. Armstrong parachuted safely to the tarmac below, but it is estimated that had he ejected just half a second later, his parachute would not have opened in time before he would have slammed into the ground from a height of 200 feet.

Ironically, the Lunar Landing Training Vehicle – the LLLTV – had been seen as being less prone to accidents than the earlier LLRV, and more like what would be experienced when trying to land on the Moon. Armstrong was soon to find out what that was really like.

By the time the 16 July 1969 came around, Apollo 8 and Apollo 10 had each flown around the Moon, but had not landed. That was to be the mission for Armstrong's Apollo 11. As the mighty Saturn V rocket blasted skywards, it was waved on by thousands of people watching below and millions of people on their TV sets. The flight to the Moon went by without a hitch and, after making 30 orbits of the Moon, the Lunar Module, named Eagle and flown by Armstrong and Aldrin, detached from the Command Module named Columbia and piloted by Collins.

The next stop for Armstrong and Aldrin was a region on the surface in the Sea of Tranquility, which is not a sea at all, but a vast lava plain. The planned landing spot had been chosen because it seemed relatively flat and safe to land on, but during the descent, Armstrong and Aldrin noticed that they were going long and would touchdown several miles beyond where they were supposed to be.

INSIDE THE APOLLO 11 SPACESUIT



HELMET

The helmet wasn't just designed to protect the astronaut from the vacuum of space, but its gold tinted visor and sunshields protected against solar ultraviolet light, heat and damage from tiny meteorites.

PLSS REMOTE CONTROL UNIT

Placed on the chest of the spacesuit, the PLSS remote control unit allowed the astronaut to control oxygen levels and suit temperature, as well as activate their radio and mount the Hasselblad camera that the astronauts used.

LUNAR BOOTS

The first famous footprints into lunar soil were left by boots that were made very much like the gloves, covered in a sturdy steel mesh and a silicone tread.

PRIMARY LIFE SUPPORT SYSTEM (PLSS)

The bulky backpack was the Primary Life Support System, or PLSS. It provided oxygen, controlled suit pressure and temperature, removed harmful carbon dioxide and monitored the astronaut's vital signs.

RADIO ANTENNA

During their moonwalk, Neil Armstrong and Buzz Aldrin were in near-constant contact with mission control on Earth, and even had a conversation with President Nixon, thanks to the antenna attached to their spacesuits.

GLOVES

Their gloves were covered in a steel fabric and their silicone-tipped fingers were dexterous enough to manipulate equipment and pick up lunar rocks.

SAMPLE COLLECTION BAG

Neil Armstrong and Buzz Aldrin returned 22kg of material from the Moon, including bags of soil and 50 rocks, for scientists to study on Earth. Their findings from the rocks have taught us a lot about how the Moon formed.

Armstrong stands by the Lunar Module on the surface of the Moon

Armstrong joined the US Navy on 26 January 1949

ARMSTRONG'S ACHIEVEMENTS

DATE OF BIRTH

5 August 1930

HOMETOWN

Wapakoneta, Ohio, United States

EDUCATION

1944
Attended Blume High School, in Wapakoneta, Ohio

1950
Qualified as US Navy aviator

1955
Graduates from Purdue University with a degree in Aeronautical Engineering

1970
Master of Science in Aerospace Engineering from the University of Southern California

Armstong also held honorary doctorates from a number of universities.

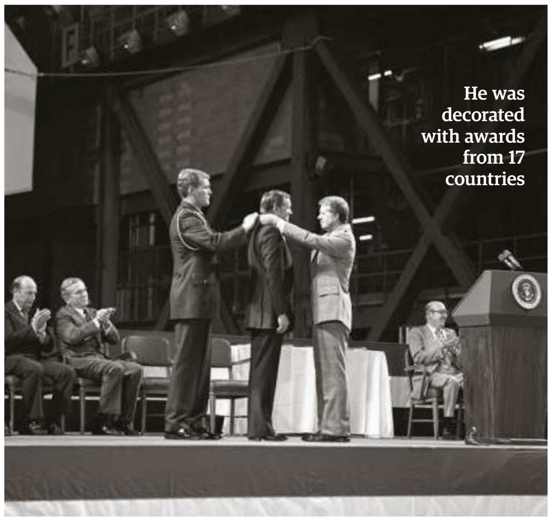
EXPERIENCE

1949-52
Served as a US Navy fighter jet pilot during the Korean War

1955-62
Test pilot for the National Advisory Committee for Aeronautics (NACA)

1962
Selected as one of the second batch of NASA astronauts

1969
Commander of the Apollo 11 mission, and the first person to walk on the Moon



He was decorated with awards from 17 countries

1970-71
Deputy Associate Administrator for aeronautics at Aeronautics, NASA Headquarters, Washington, DC

1971-79
Professor of Aerospace Engineering at the University of Cincinnati, Ohio

1986
Appointed Vice-Chairman of the Rogers Commission investigating the Challenger space shuttle disaster by President Reagan

AWARDS

1969
Presidential Medal of Freedom

1970
NASA Distinguished Service Medal

1978
Congressional Space Medal of Honour

> "In all, they were out on the surface of the Moon for just two and a half hours"

This was not good; as they neared the ground, Armstrong and Aldrin could see that Eagle was heading straight for a boulder field and should the Eagle crash into on of the boulders it could damage the Lunar Module, preventing them from blasting off again and returning home. Although Buzz Aldrin was technically the Lunar Module pilot, Armstrong, as mission commander, took control.

With fuel running low, boulders looming up below, and Aldrin constantly rattling off altitude and velocity data, Armstrong remained calm with the eyes of the world upon him. His experience in dealing with crisis situations in flight, from the Korean War to the B-29, Gemini 8 and the LLTV and numerous other instruments, now set him up for the moments that would forever define his life.

With just 45 seconds of fuel left and engineers and mission managers in Houston holding their collective breath, Armstrong expertly brought the Eagle down to the lunar surface. Then came his famous radioed message to mission control, "Houston, Tranquility Base here. The Eagle has landed."

Directly after landing, the astronauts were meant to have a sleep period to rest before embarking on the first ever Moonwalk.

Like children on Christmas Eve, however, they were too excited to go to sleep, as NASA had timetabled for them. So the Apollo 11 team prepared their spacesuits and got ready to go outside and explore the Moon. Originally, it was to be the Lunar Module pilot that would be the first to open the hatch, climb down the ladder and planet the first footstep into lunar soil. However, before launch this was switched so that Armstrong would be first out.

The official reason given was because of the positioning of the hatch, which would make it difficult for the Lunar Module pilot to climb out first, but unofficially mission managers had doubts about Buzz Aldrin and his 'ego'; they saw Armstrong as the more professional of the two.

Also, "just on a pure protocol basis, I figured the commander ought to be the first guy out," remembered Deke Slayton, the head of NASA's astronaut office and himself an astronaut. A fuzzy video feed, watched by over half a billion people back on Earth, recorded what happened next. Armstrong, garbed in his bulky space suit, the portable life support system on his back, climbed down Eagle's ladder, before pausing.

"I'm at the foot of the ladder," he said, describing the ground below him. "The LM footpads are only depressed in the surface about one or two inches, although the surface appears to be very, very fine grained, as you get close to it. It's almost like a powder. Down there, it's very fine." Another pause. "I'm going to step off the LM now." Twisting around, Neil Armstrong dropped down onto the surface of the Moon. "That's one small step for [a] man, one giant leap for mankind," he said, words that will live long into the future.

They were also words that led to a degree of controversy. Did he or didn't he say 'a' before 'man'? Armstrong initially was adamant that he had and that it was only the poor radio link that had caused it to be inaudible, but later in his life he became unsure, while various studied analysing the recording often produced differing opinions. Nevertheless, everyone knows what he meant to say.

Armstrong was out alone on the lunar surface for nearly 20 minutes before Buzz Aldrin joined him. Together they planted the Stars and Stripes of the United States flag, had a telephone call with President Richard Nixon, and collected some moon rocks to bring home for scientists to study.

In all, they were out on the surface of the Moon for just two and a half hours. It's a curious fact of history that there are hardly any photographs of Armstrong on the surface of the Moon. That's because they only had one camera with them, and Armstrong carried it for the most part. There was little time for larking about; their scientific tasks were planned to the minute.

"It has a stark beauty all its own," Armstrong said of the desolate lunar landscape. "It's different but it's very pretty out here."

There was one final drama to play out. Back inside the Eagle, Armstrong and Aldrin prepared to lift off for rendezvous with Michael Collins in the Columbia, where they noticed that the switch to fire the rocket ignition had broken off - presumably it had been knocked off by their bulky backpacks. Without being able to fire the engine, the two astronauts would never be able to go home.

Indeed, President Nixon had two speeches prepared: one to celebrate a successful mission, and another to mourn two lost astronauts stranded on the Moon to die.

Fortunately, he got to read the celebratory speech. Buzz ingeniously jammed a ballpoint pen into where the switch was meant to be, the engine fired, and they departed the Moon.

After meeting and docking with Columbia, the three astronauts headed for Earth, ultimately splashing safely down into the Pacific Ocean to soon be retrieved by the USS Hornet.

After time spent in quarantine (in case they brought back any bugs from the Moon) the crew of Apollo 11 went on a worldwide tour, after which Armstrong announced his retirement as an astronaut.

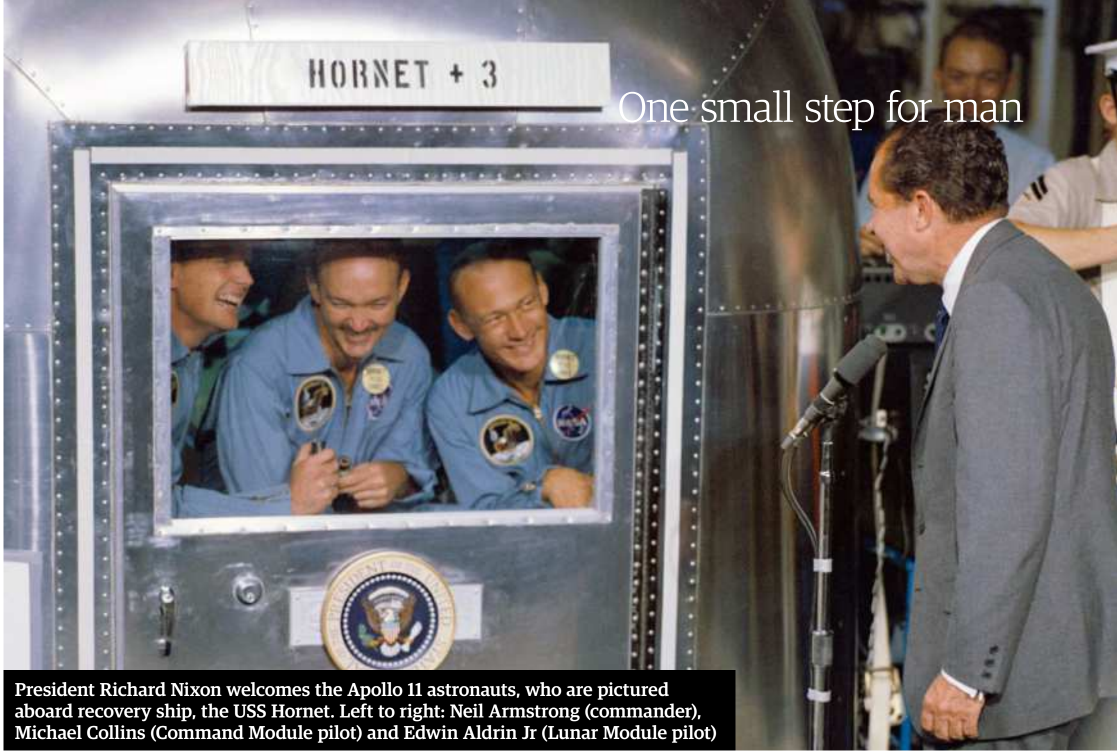
After all, once you've been to the Moon and back, how can you beat that?

His life after Apollo 11 was distinctly more low key than his life before the mission, as he stayed out of the limelight.

For eight years he taught aeronautical engineering at the University of Cincinnati. He also served on the accident investigation boards for both Apollo 13 and the Challenger disaster in 1986.

Away from NASA and teaching, Armstrong served as a director for several companies. He divorced his first wife, Janet, in 1994 and married his second wife, Carol Knight, that same year. Although he seldom drew too much attention to himself, he often spoke publicly at NASA events, right up until his death on 25 August 2012 at the age of 82 as the result of complications following a heart bypass.

Even now it is still a shock that he is no longer with us, but a 1,000 years from now, everybody will still remember the name of Neil Armstrong, the first person to walk on the Moon.



President Richard Nixon welcomes the Apollo 11 astronauts, who are pictured aboard recovery ship, the USS Hornet. Left to right: Neil Armstrong (commander), Michael Collins (Command Module pilot) and Edwin Aldrin Jr (Lunar Module pilot)

'NEIL ARMSTRONG TOOK CONTROL'

BUZZ ALDRIN REVEALS HOW DISASTER ALMOST STRUCK THE APOLLO 11 MISSION

APOLLO 12 ALMOST BECAME THE MISSION TO LAND MEN ON THE MOON, RATHER THAN APOLLO 11. WHAT HAPPENED?

Originally it was scheduled for Apollo 11 to be the first lunar landing, then evidently without notifying the nation and the crew, it slipped to being Apollo 12 because of the overweight condition in Apollo 11's original design.

It needed to be light enough to land, so they kept kind of working on it and not disclosing until a final decision was made. And so history was gonna play out a different way. And that again had a major impact on my life and career, and Neil Armstrong's career, if it had remained too heavy to make a landing attempt.

YOU AND ARMSTRONG RAN INTO SOME PROBLEMS DURING THE APOLLO 11 MISSION, COULD YOU TELL US MORE ABOUT THAT?

About four minutes into the landing sequence of Apollo 11, the display on the computer read 1201 and 1202. They were error codes, the number of the alarm, and whatever information was displayed before - whether it was velocity or movement over the ground - was not there any more.

WERE YOU WORRIED?

These codes were disturbing and distracting, but Mission Control didn't know what the alarms meant either. Neil Armstrong, who was paying more attention than I was since he was looking out of the window, took manual control. There were craters drifting by, but not many of them were identifiable. Neil said he thought we may be a little long - the Eagle had overshot its planned landing site.

The fuel tank was running low and Neil understood this. By experience, there were two minutes of fuel remaining and ahead was a crater that looked dangerous with giant rocks around it.

The easiest thing to do was just slow the rate of descent and fly over whatever it was, but that would take longer and burn more fuel and make fuel quantity at touchdown a little less. We were just over 30 metres (100 feet) from the surface, and Neil had to land somewhere.

WHAT HAPPENED NEXT?

I could see the shadow getting bigger because the Sun was behind us, and we were getting closer and closer to the shadow of the lander.

The dust began kicking up and, without trying to disturb Neil's concentration, I gave him a little body language to get on the ground as soon as possible.

And then it happened.

We touched down safely in the Sea of Tranquillity. There had been just 15 seconds of fuel spare.

WERE THERE ANY OTHER TEETHING TROUBLES?

We then had a problem with the hatch. The pressure inside had to be low, but when we tried to pull the hatch down it wouldn't come open.

I bent the door back and equalised the pressure. I watched out the window to see Neil go down the ladder. When it was my turn to back out, I remember the checklist said to reach back carefully and close the hatch, being careful not to lock it.

It would have been very difficult to open it from the outside if I had.

The Moon's surface can be best described as utter desolation, with no signs of life whatsoever.

There were a few hours to collect precious rock samples and carry out experiments.

Once we were ready, I looked around at some of the lunar dust on the ground and saw the broken end of a circuit breaker. One of the spacesuits had knocked it out, but it was needed to start the engine and get us back home. The broken parts that were still on the inside had to be pushed in, and only two people could fix this.

So, in the countdown procedure, I used a pen to push the circuit breaker in. This worked and the engine started. We could go home.

© Alamy, NASA

BUZZ ALDRIN: TO THE MOON AND BEYOND

American hero, second man on the Moon, Mars advocate – whatever you call him, Buzz Aldrin will remain one of the most important space pioneers in history. When he talked to us, we listened...

Interviewed by Jonathan O'Callaghan

On 20 July 1969, Edwin "Buzz" Aldrin's life changed for ever. Following his friend and fellow astronaut Neil Armstrong onto the lunar surface, Aldrin was instantly immortalised as the second man on the Moon, and one of only 12 to have ever set foot there. With Armstrong's death in August 2012, Aldrin is the sole survivor of one of the most famous double-acts the world has ever known.

But while they may have shared that out-of-this-world experience together, the duo would go on to lead vastly different lives. Armstrong chose a life of solitude and isolation, preferring to shy away from the public eye and retire to his farm in Ohio, USA, while Aldrin became a vocal proponent for manned exploration, keen to share his views with the world - something he continues to do to this day.

So when we had the chance to talk to Aldrin about his career at NASA and his life afterwards, we knew he wouldn't be adverse to giving his views on everything from the Gemini missions to the current state of NASA, and he duly obliged.

"I chose my career in the air force as it evolved to not include test pilot training," he admits, as we talk about his pre-NASA career. "I wanted to focus on the future in space. I knew I was a good pilot, but I didn't want my [life] to depend on how co-ordinated and precise I was [if I became a test pilot], so I was looking towards academic research."

While Aldrin's beginnings as a pilot were similar to many of the Space Race era of astronauts - and indeed many modern ones as well - his decision to avoid advancing to the level of test pilot made him almost unique at the time. Whereas those such as Neil Armstrong spent time flying experimental jets like the X-15 rocket-powered aircraft, Aldrin devoted his time to the study of space architecture - specifically a thesis on 'Manned Orbital Rendezvous', which would later earn him the nickname 'Dr Rendezvous' when he joined NASA.

When he did eventually enter the USA's national space agency in 1963, he was thrust into a pitched technological battle between the USA and the Soviet Union. It's hard to deny that the Space Race between those two superpowers during the Sixties and Seventies remains the most exciting time for human space exploration in the history of humankind. Our modern missions to the International Space Station sometimes fail to elicit the same kind of awe and wonder. But as thrilling as those early missions may have been, they were fraught with peril.

Aldrin was very close friends with Ed White, who performed the first American spacewalk in June 1965 before sadly losing his life, along with Gus Grissom and Roger Chaffee, in the Apollo 1 fire in April 1967. It was White who inspired Aldrin to get involved with NASA. "In 1962, I got a phone call from Ed White, and he said NASA was selecting the second group of astronauts," says Aldrin. "I told him I could shoot gunnery as well as him, or better, so I also decided to apply. But even though I was studying for a doctor of science degree at the Massachusetts Institute of Technology [MIT], I wasn't selected [because I didn't have test pilot experience]." By 1963, though, the requirements had changed and Aldrin no longer required test pilot training to become an astronaut. He applied, and was eventually selected as a member of the third group of 14 NASA astronauts.

Aldrin's academic background stood him in good stead. "I believe there were several of us in that third group who had not been trained as test pilots," he says, "but at the time I was the only one who had a doctorate's degree from as prestigious a place as MIT." His knowledge and work would prove pivotal in the eventual success of the Apollo missions.

Buzz Aldrin in his Apollo 11 spacesuit

"At the beginning of the Gemini programme, four objectives were at stake," explains Aldrin. "Long-duration human spaceflight, computer-guided re-entry, space EVA [extravehicular activity, or spacewalks] and, of course, rendezvous in space between Gemini and another spacecraft. Operating independently outside of the spacecraft was essential for the Apollo programme."

But when Aldrin was ultimately assigned to fly on the Gemini 12 mission in 1966, NASA was still struggling to get to grips with EVAs. Aldrin felt that he would be able to help NASA perfect the technique, so that the Apollo missions could go ahead, but at one stage it looked like he wouldn't even get the opportunity to go to space. "I was helping to train the early rendezvous missions and I expected to be assigned eventually to a primary crew before the end of the Gemini programme [under NASA's three-mission rotation schedule]," Aldrin explains. "Unfortunately, it didn't look like it was going to work out that way because my assignment with Jim Lovell was to back up Gemini 10, which meant we would fly as the primary crew on Gemini 13. But there was no Gemini 13. So it was a disappointment to me to be assigned as a dead-ended participant in the Gemini programme."

Aldrin and Armstrong became celebrities around the world after returning from the Moon

Aldrin on board the Eagle lunar lander

As fate would have it, however, Aldrin would ultimately get his flight when some of his fellow astronauts lost their lives in tragic circumstances. "The primary crew of Gemini 9, consisting of Elliot See and Charlie Bassett, were flying in to St Louis [Missouri, USA] in a snowstorm," says Aldrin. "They became disoriented on their final approach and they crashed into the hangar that housed their spacecraft and both were killed. So Jim Lovell and I were moved up to back up Gemini 9, which meant we'd rotate to be the prime crew on Gemini 12. My growth as an astronaut took on a very major change because of the tragedy of the loss of a crew."

Despite the sombre conditions around which his mission had arisen, Aldrin was ready to grasp the opportunity. He began to train underwater in what is known as neutral buoyancy ahead of his important EVA. On 11 November 1966, Aldrin, alongside Jim Lovell, launched into space, and the mission he had trained for and worked on for so long could begin. He did three EVAs totalling "five and a half hours, and I set a world record [for EVA length at the time] and successfully accomplished all the tasks in the back of the spacecraft using foot restraints, which had been vastly improved. Based upon that, we moved into Apollo confident of the spacewalking experience."

> "We moved into Apollo confident of the spacewalking experience"

Aldrin's successful last mission in the Gemini programme put him in a "rather good position for assignment on Apollo as the programme evolved after the [Apollo 1 launchpad] fire that killed my good friend Ed White, which set back the early design of the Apollo spacecraft when the Russians were moving ahead rapidly. Neil Armstrong and I ended up on the backup crew of Apollo 8."

Just as his flight on Gemini 12 might not have happened, though, Aldrin also revealed to us how Apollo 11's status as being the first landing on the Moon was at one stage in doubt. "What had been happening in the evolution of Apollo was that Apollo 11, when it was assigned its crew, was potentially going to be the first landing mission," explains Aldrin. "However, I've recently learned from the programme manager, Hugh Davis, that Lunar Excursion Module 5 [LEM 5, the Apollo 11 Eagle lunar lander], which was scheduled to fly on Apollo 11, was originally not qualified for landing. It was overweight."

This revelation meant that, for a time, it looked like Apollo 12 would be the first lunar landing, and not Apollo 11. "It wasn't until quite recently that I discovered that there was a period of time where the first landing was going to be Apollo 12 in October, and not Apollo 11 in July," explains Aldrin. "So history was going to play out a different way, and that again would have had a major impact on my life and career, [as well as] Neil Armstrong's, if LEM 5 had remained too heavy to make a landing attempt."

Eventually, however, the problems were overcome and Apollo 11 was given the go-ahead, although the crew "were apprehensive doing something for the very first time." Aldrin and Armstrong touched down on the Moon on 20 July 1969. On the surface, Aldrin described the Moon as "magnificent desolation", which is also the title of his 2009 autobiography. "When I got on the surface after hearing Neil's words ['One small step for man, one giant leap for mankind'], I then heard him use the word 'magnificent'," says Aldrin. "That reminded me to add something to his words, so I said 'magnificent desolation'. That word 'magnificent' means to me the progress, the evolution of humankind on planet Earth. The contrasting word of 'desolate' means that what Neil and I were looking at was perhaps the most desolate scene we had ever seen. Absolutely no life whatsoever, just shades of grey and a black sky, no air, no evidence of life at all. You just couldn't re-create that scene of desolation."

On their return to Earth, Aldrin and Armstrong were thrust straight into the glare of the global limelight. Whereas Armstrong chose a life of isolation, Aldrin instead became a space expert on a range of policies, never afraid to speak his mind, which is the case to this day. We ask his thoughts on the state of space exploration today, with the 50th anniversary of the Apollo 11 mission approaching in 2019, and he is keen to give his opinion on where he thinks we stand.

IN THE FOOTSTEPS OF BUZZ ALDRIN

20 Jan 1930 Birth
Edwin Eugene "Buzz" Aldrin is born in Montclair, New Jersey, USA.

1951 West Point
Graduates from West Point Military Academy in New York.

1963 Doctorate
Receives his doctorate of science in astronautics from MIT.

Nov 1966 Gemini 12
Performs the first wholly successful spacewalk during the Gemini 12 mission.

20 July 1969 Apollo 11
Aldrin and Neil Armstrong become the first people to walk on the Moon.

Mar 1972 Retirement
Aldrin retires from active duty after 21 years of service.

1989 Men From Earth
Releases a book about the Apollo programme called *Men From Earth*.

2009 Magnificent Desolation
Buzz's autobiography *Magnificent Desolation* is published.

Aldrin is clear in his belief that international co-operation will be key for future space endeavours, but he wants the USA to continue to lead the field. "With the ISS I think we have learned that, even though it maybe wasn't perfect, we did bring nations together," he says. "There are other things that we've co-operated on in space, but I feel that we need an international lunar base development so that activity on the Moon - robotic or human - can be overseen by a single international organisation, and it should be instigated and led by the United States."

Indeed, Aldrin feels that a lunar base could be a vital stepping stone to other corners of the Solar System. "In the conservation of our resources in the US, we should prepare a lunar base for other people to use including testing spacecraft and later interplanetary travel," explains Aldrin. "That way we don't have to build the big rockets and big landers that we're not well equipped to do."

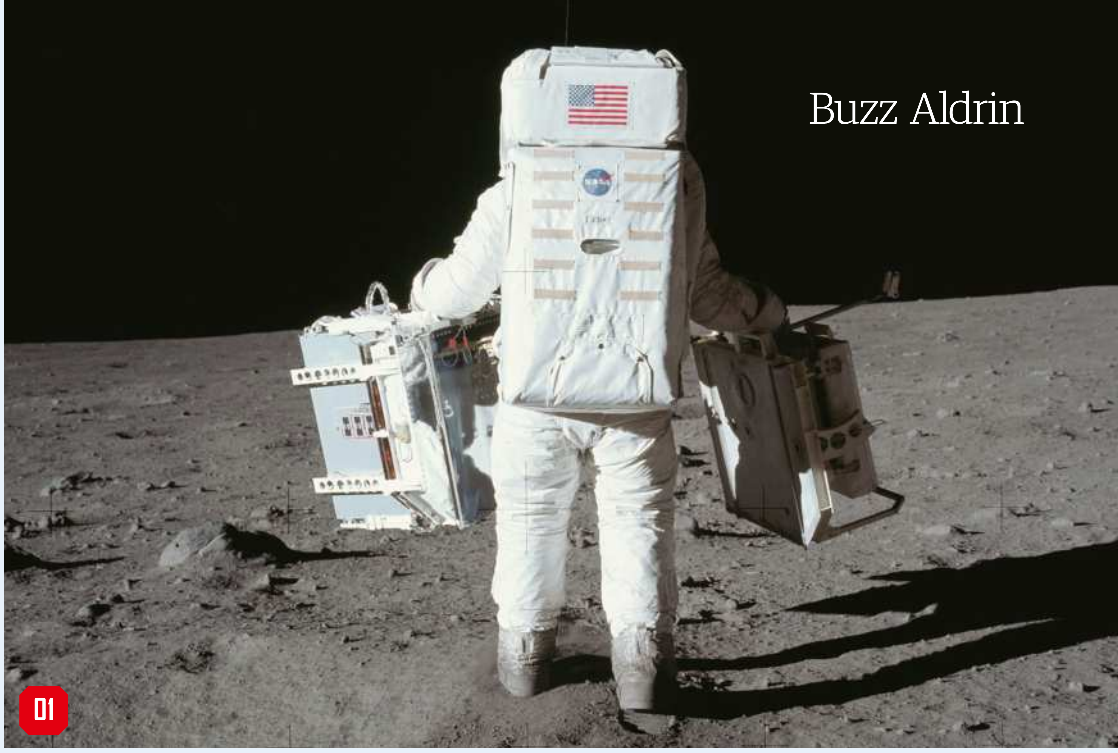
Aldrin, of course, is referring to NASA's much-maligned Orion spacecraft and Space Launch System [SLS], which he feels are stagnating under misdirection. President Obama was responsible for cancelling the Constellation programme, which would have landed astronauts back on the Moon, but Aldrin feels it was a step that needed to be taken. "He was following the unsuccessful implementation of President Bush's plan," says Aldrin. "Obama made the right decision in cancelling Constellation."

But even with the deadweight of Constellation cast off, Aldrin still feels NASA's current goal for manned exploration is wrong. "Orion and SLS are not the right direction for NASA," he says. "I think we're so far along with Orion that we need to complete it as an Earth-landing system, but I think Orion needs to have a second-generation spacecraft that does not re-enter the atmosphere, and I don't believe we need to develop a big rocket that will be very expensive and won't fly very often."

The problem, Aldrin says, is with the Senate. "Senate law mandates NASA to use 'heritage components'," he explains. "That, to me, means old stuff. Not innovative future thinking that is commemorative of a great leading nation. If this is continued, it will not bode well for US leadership in space. We should be landing astronauts on the Moon, and we've got plenty of time to develop a more cost-effective system than using 'heritage components'."

While the US government might be heading in the wrong direction in Aldrin's eyes, the privatisation of space is something to be hopeful for. "I'm encouraged by commercial space initiatives," he says. "Their success will move the country towards landing man on Mars, and not returning to what we did 40 or 50 years ago [on the Moon]. For a while I have felt that the public attention being drawn to the 50th anniversaries of the landings on the Moon from July 2019 to December 2022 - that's the landing of Apollo 11 through 17 - might inspire such a mission. I think those are attractive times to make a commitment to permanence at Mars within two decades."

As we head into this new era of private space travel, the man who was on that seminal mission to the Moon clearly feels that now is the time to, once again, reach for the stars just as we did in the Sixties and Seventies. And does Aldrin think Mars is a realistic target by 2035? "Yes, I do," he concludes.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02

1. On the Moon
Aldrin carries two packages that made up the Early Apollo Scientific Experiment Package.

2. Gemini 12
Aldrin (left) with his fellow Gemini 12 crewmember, Jim Lovell.

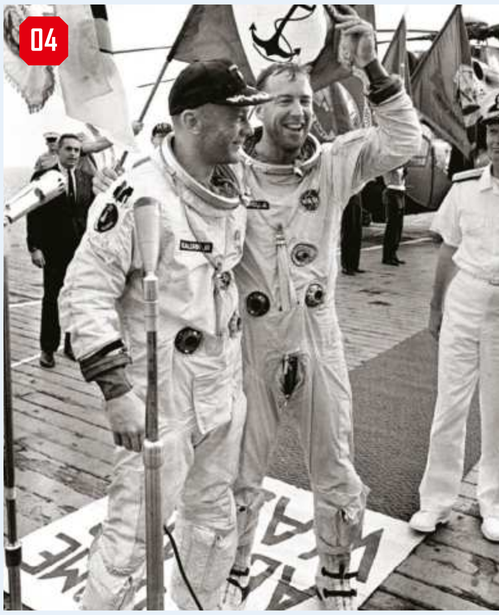
3. Spacewalk
Aldrin helped perfect spacewalks while on board Gemini 12 and set a world record for EVA length.

4. Splashdown
Lovell and Aldrin pictured aboard the USS Wasp after Gemini 12 splashed down in the Atlantic Ocean.

5. Nixon
Armstrong, Collins and Aldrin talk with President Nixon after their return from the Moon.

6. Obama
The Apollo 11 crew meet President Obama in the White House in 2009.

03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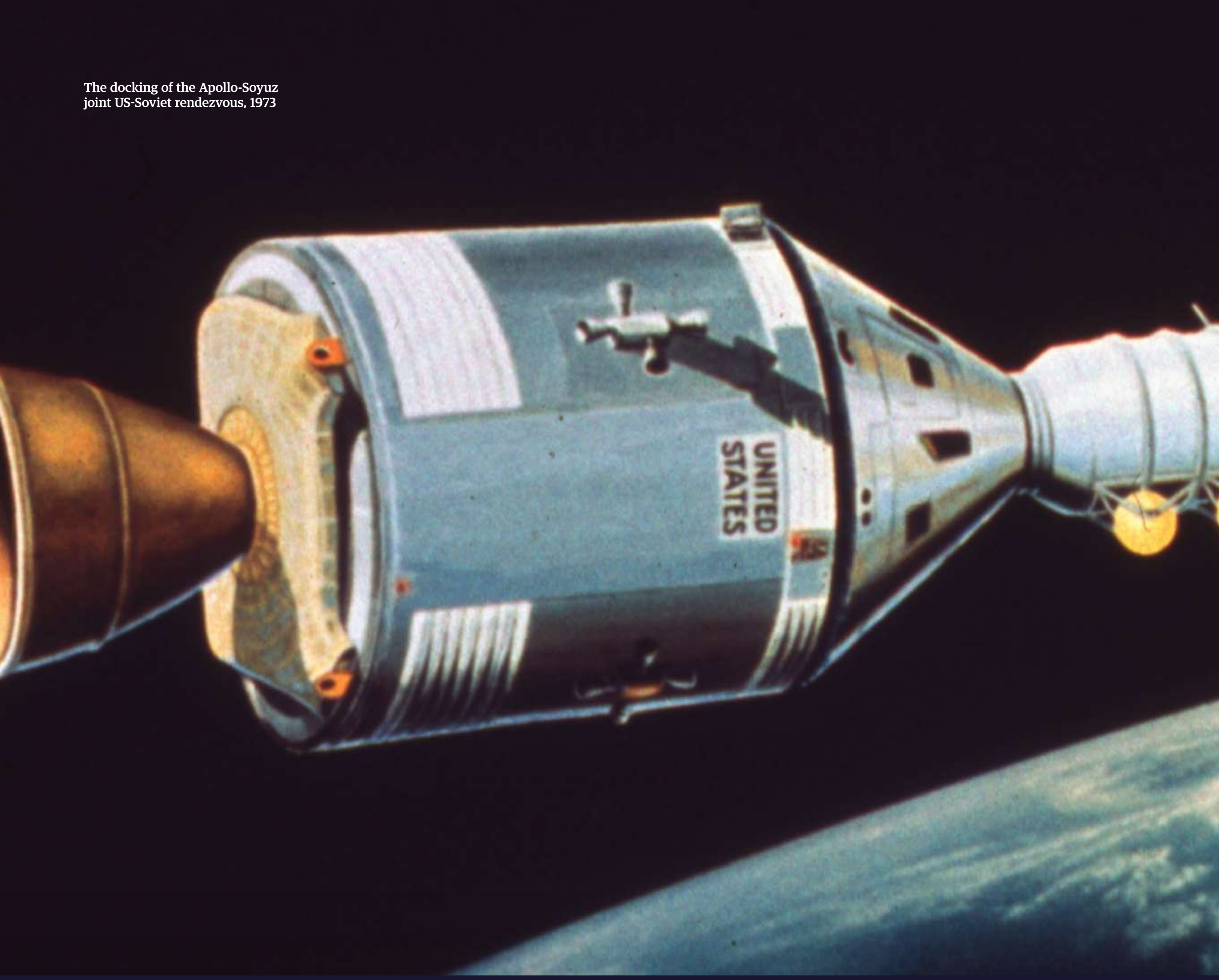

The docking of the Apollo-Soyuz joint US-Soviet rendezvous, 1973

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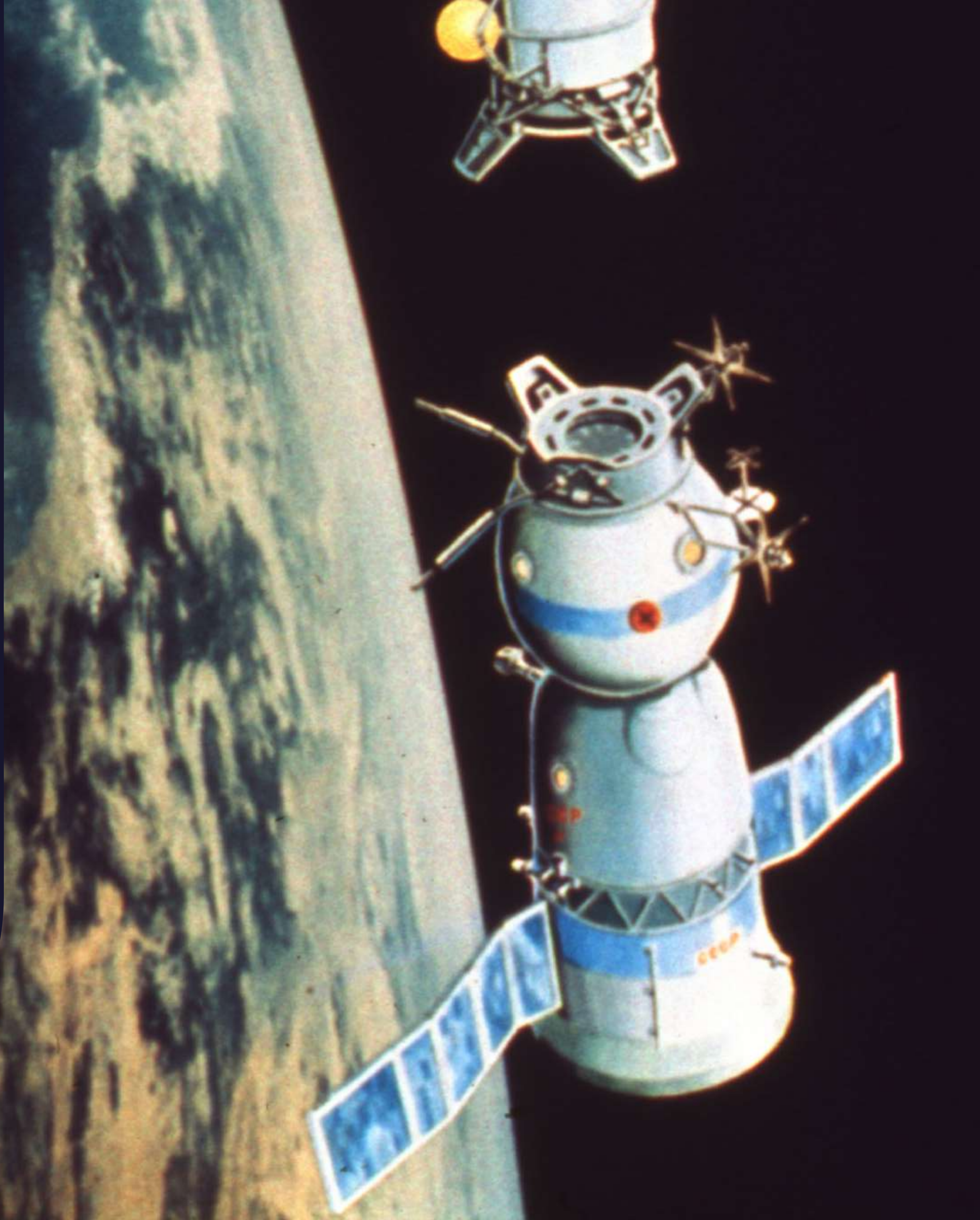
1970s
& BEYOND

SPACE ★ RACE



HOUSTON, WE'VE HAD A PROBLEM

The mission that missed the Moon – how the crew of Apollo 13 made it home safely against all odds

★ **Written by April Madden** ★

After performing two successful Moon landings, NASA had pulled ahead of the Soviet Union as the undisputed leader in the Space Race. But a potentially fatal accident on its third lunar surface-bound mission was about to bring it back down to Earth.

Apollo 13 was surrounded with superstition from the start, the number 13 believed to be unlucky, but NASA wasn't going to let that get in the way of science. The public and the press, however, seemed more focused on the mission's designation than its aims, with many questioning why NASA even needed to revisit the Moon after the successes of Apollo 11 and 12. NASA knew these landings were more than just a novelty, so the Apollo program continued - for now - and Deke Slayton, director of Flight Crew Operations at the time, put forward his suggestion for the Apollo 13 crew.

Slayton's proposed line-up had Alan Shepard, one of the original Mercury Seven, as commander, but management, concerned Shepard might be out of practice after surgery to correct his Ménière's disease, which had grounded him since 1963, rejected the proposal. Not wanting to split up his crew, instead the entire Apollo 14 crew was brought forward.

Previously the back-up crew for the historic Apollo 11, the crew was commanded by Jim Lovell, a NASA veteran who had flown across the Gemini and Apollo programmes, with command module (CM) pilot Ken Mattingly and lunar module (LM) pilot Fred Haise, both of whom hadn't yet been to space.

The crew trained rigorously in the months leading up to launch, going through figures and simulations to get them used to the confined workspace and testing their responses to the multitude of things that could go wrong in-flight. All of their training had prepared them for just about any eventuality, but soon things would start going wrong.

Just seven days before launch, the back-up LM pilot, Charlie Duke, contracted rubella, or German measles, from one of his children. Since the crew had been training in close proximity to their back-ups, this meant that everyone had been exposed, risking infection. A look through their medical histories showed that the only one who hadn't already had the disease was Mattingly, and the timeframe meant that he was at risk of showing symptoms while in control of the CM. The entire mission was jeopardised.

With less than a week to decide what to do, the pressure was on. Mattingly insisted he was good to

> "Since the crew had been training in close proximity to their back-ups, this meant that everyone had been exposed"

The crew made a successful landing in the Pacific Ocean

Fred Haise on screen in the Mission Control room

U.S.S. IWO JIMA
ASTRONAUT
HAISE
APOLLO 13
U.S.S. IWO JIMA
ASTRONAUT
SWIGERT
APOLLO 13
U.S.S. IWO JIMA
ASTRONAUT
LOVELL
APOLLO 13
NASA

The crew on USS Iwo Jima after recovery from the CM

fly, while the flight surgeon said the risk was too great. Switching to the back-up crew wasn't an option seeing as Duke was out of commission with illness, so NASA would have to go against protocol and place back-up CM pilot John 'Jack' Swigert on the mission, though Lovell fought all he could to keep his crew together before conceding. Three days of intense training followed to make sure the team could work as one, and the mission was kept on schedule for 11 April 1970.

Happy to proceed as scheduled with the last-minute crew changes, the day of the launch came. The three men boarded the CM, nicknamed Odyssey, at the tip of a Saturn V rocket at the Kennedy Space Center in Florida. Here NASA was reminded again of waning interest in space exploration with a launch turnout of around 200,000 people – it was a crowd that paled in comparison to the 7 million who had come to see Apollo 11 lift off almost a year earlier.

The launch was completed at the scheduled time, the Saturn V rocket achieving orbit with just a minor problem when its second-stage inboard engine stopped firing prematurely due to the intense vibrations. Luckily their course was easily corrected by burning the four outboard engines and the third-stage engine a little longer, and the crew was

TIMELINE OF APOLLO 13

LIFTOFF
14:13 EST / 19:13 GMT

LM DOCKING
3:19.09
INTO MISSION

MID-COURSE CORRECTION
30:40.50
INTO MISSION

OXYGEN TANK EXPLOSION
55:54.53
INTO MISSION

DECISION TO RETURN TO FREE-TRAJECTORY RATHER THAN DIRECT ABORT
56:48
INTO MISSION

DECISION TO POWER UP THE LM
57:38
INTO MISSION

CM POWERED DOWN
58:40.00
INTO MISSION

FREE-RETURN TRAJECTORY CORRECTION
61:29.43
INTO MISSION

CARBON DIOXIDE BUILD-UP CONCERNS, RESEARCH ON CM CANISTERS BEGINS
63:32
INTO MISSION

POST-PERICYNTHION TRAJECTORY CORRECTION
79:27.39
INTO MISSION

LM POWERED DOWN
79.34
INTO MISSION

CARBON DIOXIDE REMOVAL PROCEDURE READY
87:00
INTO MISSION

MID-COURSE CORRECTION
105:18.28
MISSION

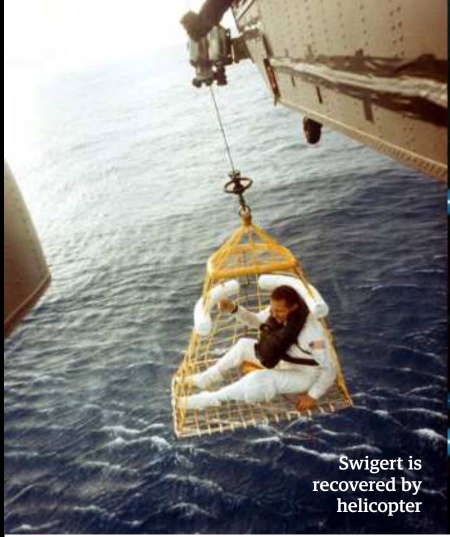
CM POWERED UP FOR RE-ENTRY
136:25
INTO MISSION

SM SEPARATION
138:01.48
INTO MISSION

LM UNDOCKING
141:30.00
INTO MISSION

ENTRY INTERFACE
142.40.46
INTO MISSION

LANDING IN THE PACIFIC OCEAN
142:54.41
INTO MISSION


Swigert is recovered by helicopter

Swigert (left) and Lovell investigate the CM after landing

seemingly safe, heading for the designated lunar landing site of the Fra Mauro highlands. After pulling away from the exhausted third stage and successfully docking Odyssey to the LM Aquarius, Lovell, Swigert and Haise settled in for the rest of their journey to the Moon.

But things weren't to go as planned. Approaching 56 hours into the mission and around 330,000 kilometres (205,000 miles) from home, the crew had just ended a live TV broadcast – though not many TV stations were interested enough to show it. Noticing a slight drop in pressure, Houston flight controllers wanted to check the oxygen levels in the service module (SM), so they asked Swigert to perform a routine cryo stir on the tanks. This is where things went horribly wrong.

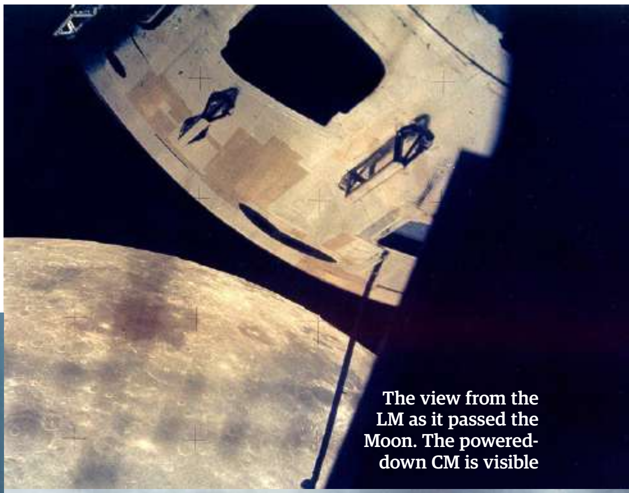
The crew heard a loud bang from outside and called down to Houston to report. Both the crew and the ground team noticed that the oxygen tanks and fuel cells were showing alarming readings, with oxygen tank two completely depleted and tank one falling at a steady rate. Several people at Mission Control assumed this was a fault with instrumentation, as no simulation had ever shown such equipment failure, but Lovell reported he could see a gas leaking out of the SM, confirming their readings were worryingly correct.

They would later discover that a current overload in an oxygen tank during routine testing shorted out the heater switch and had fused the circuit breaker shut, turning the tank into a bomb. A bomb that had been set off when Swigert had started the stir, and blown a 3.9-metre (13-foot) panel off the SM. With power and oxygen failing fast, Apollo 13's mission was no longer a lunar landing, but returning home.

Mission Control had to think quickly, calling in staff in the middle of the night and running emergency simulations. Debate raged on if the crew should be instructed to manoeuvre towards Earth straight away to return quicker, but Gene Kranz and others argued that propulsion couldn't be relied on at current power levels.

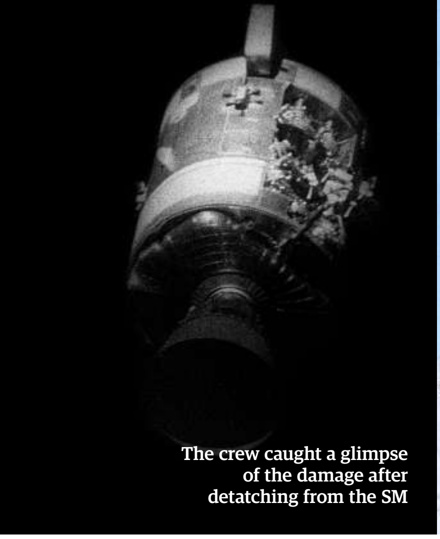
It was decided that the remaining fuel cell for the CM needed to be preserved for re-entry, since this was impossible in the LM. The crew would need to power down the CM and evacuate to the Aquarius, which could be used as a lifeboat since it had its own life-support system. This, however, presented problems: the LM was only designed for two astronauts to visit the Moon for around 20 hours, whereas their trip home would be four or five days. Also, engineers weren't sure if the SM would power back on after being inactive for so long. Still, there wasn't much choice. The crew was instructed to power up the LM and transfer guidance parameters from the CM before powering it down. It usually took three to five hours to power up a LM – they had just 90 minutes.

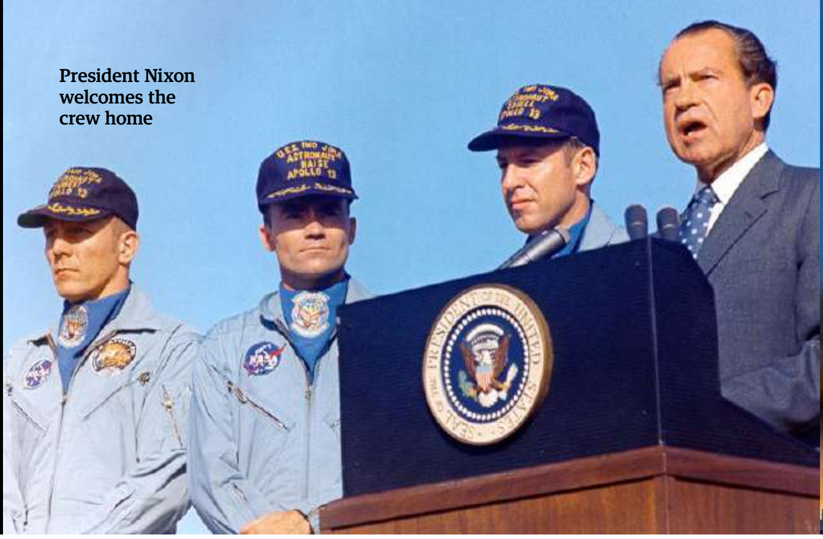
The next hurdle was aligning the LM to the correct attitude, Swigert having to read out coordinates so that Lovell and Haise could manually relay this to the LM. As soon as the situation was stabilised, Swigert joined them in the LM and the CM powered


The view from the LM as it passed the Moon. The powered-down CM is visible

Honolulu Star-Bulletin
Nixon to Greet Them Here
Astronauts Safe
Lovell reads a newspaper account of the recovery

There were worries the parachutes wouldn't deploy on re-entry


The crew caught a glimpse of the damage after detatching from the SM


President Nixon welcomes the crew home

Apollo 13 launched on a Saturn V rocket

down completely. Everyone on the ground was hard at work performing simulations and calculations to work out how the crew could get home. Before the explosion the spacecraft had departed its free-return trajectory – a method of using the Moon's gravity to return to Earth – in preparation for the lunar landing. This meant that the craft would need to realign itself, as it didn't have the power to make it back without this assist. But this was a problem, as the propulsion system on the SM couldn't be used. The crew would have to attempt trajectory correction using only the thrusters on the LM, which were designed for descent to the Moon.

Calculations from Mission Control were passed to the crew, who successfully re-entered free return with expert piloting. However, their problems weren't over. Though they had plenty of oxygen, it was realised that the LM was still using a lot of power, and didn't have enough water on board to cool all the electrical equipment. The crew was instructed to turn off everything non-essential, leaving them with a small light, a fan and a radio to keep in touch with Houston. They also had to ration their water to one-fifth of normal consumption, risking dehydration. Back on Earth there was renewed interest in the mission, with disaster drawing the public eye and the whole world wondering if they would make it. Many countries including, surprisingly, the USSR, offered any help they could to get the men home.

As the craft drifted 254 kilometres (157 miles) beyond the far side of the Moon, another manoeuvre was planned to speed up the journey to be performed two hours after pericynthion, the closest approach to the Moon. It was also debated whether the SM should be jettisoned to increase speed further, but some argued this could expose the CM's heat shield to the freezing cold of space for too long, risking it breaking on re-entry. This would also involve using all remaining fuel, meaning no other course corrections could be performed later. NASA chose the safer option of a four-minute burn, which would shave off 12 hours of flight and put the craft on target with the Pacific Ocean.

Almost 24 hours after the explosion, the crew completed another successful burn. However, now carbon dioxide levels were rising. The scrubbing system aboard the LM wasn't designed to filter air for three, and calculations saw that the lithium hydroxide canisters that removed the CO_2 would not support the crew until return. The CM had its own supply of canisters, but because of a different design these were incompatible. It was up to Houston to find a makeshift filtration method using only items on board Apollo 13. Within 35 hours of testing they had a fix utilising spacesuit hoses, plastic bags and duct tape. The next challenge was directing the astronauts how to copy their instructions, as if assembled incorrectly there was no hope of return.

> "The oxygen tanks and fuel cells were showing alarming readings"

With the filters safely in place and the crew maintaining a fine balance between power use and heat so that the CM wouldn't freeze, concerns grew about the trajectory once more. Swigert was convinced they were coming in too shallow, meaning they would bounce off the atmosphere and be lost to space. Another manoeuvre was planned to correct this, but the three pilots would have to use the Sun and Earth's terminator as a guide – the guidance systems would use up too much valuable power. Exhausted and dehydrated, the crew pulled it off, but the next problem was whether the CM would even power up. Luckily, during Apollo 10 a procedure had been simulated where the LM could charge the CM, though this involved manipulating several circuit breakers in order to backflow power.

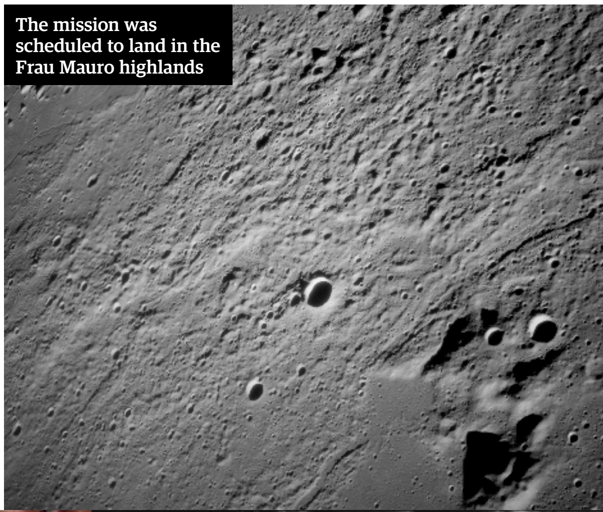
On course and with power rerouted, things were looking up. However, there were still fears that the explosion may have damaged the heat shield on the SM, which would cause it to burn up on re-entry, or that the long journey may have frozen its parachutes closed. With just hours to go, the crew moved back into the CM with just enough power for re-entry. Ground control went over final procedures, and the crew prepared for the worst.

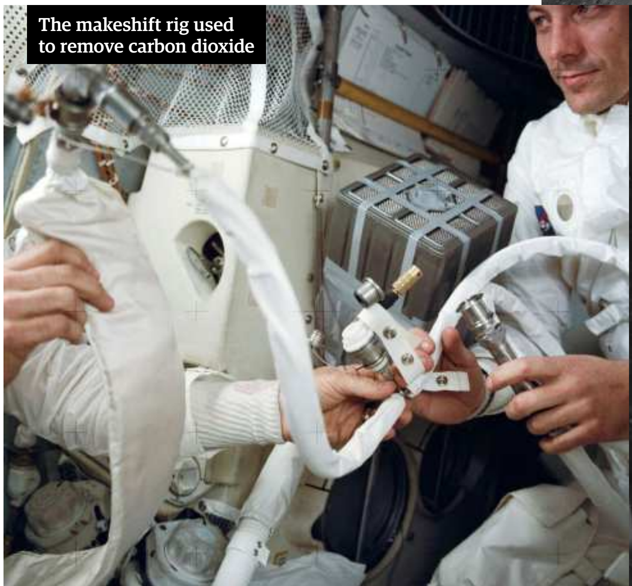
Next was to jettison the damaged SM while using the LM thrusters to move a safe distance from it. This was the first time the crew saw the extent of the explosion, relaying the damage down to the ground. The LM jettison was next, and a special last-minute procedure had been designed to keep distance by pressurising the connecting tunnel before release. Calculations were a success, and the crew bid farewell to Aquarius, the reason they had made it this far.

As Odyssey began its descent, tensions were high and the world was watching. Ionised air around the craft upon re-entry meant a total communications blackout, and for over four minutes NASA had no contact, fearing the shields or parachutes could still fail. After a longer-than-expected blackout, the crew finally made contact. They had made it home, splashing down in the Pacific Ocean to be picked up by USS Iwo Jima.

The mission was dubbed a successful failure, proving NASA could work well in a crisis. However, without the combined efforts of both the crew and the ground team, it's likely the mission would have been lost forever.

© NASA


The mission was scheduled to land in the Frau Mauro highlands


The makeshift rig used to remove carbon dioxide

Haise prepares the LM Aquarius to be jettisoned

SOYUZ 11

The tragic mission that changed spaceflight forever

To date, more than 500 people have gone to space, but only three have ever died in space itself. They were the crew of the Soviet Union's Soyuz 11 mission, and their story is one of both accomplishment and tragedy.

The three crew members of Soyuz 11 were Georgi Dobrovolski, Vladislav Volkov and Viktor Patsayev, but they were not supposed to have been. Originally, the crew consisted of Alexei Leonov (the first man to walk in space), Valeri Kubasov and Pyotr Kolodin. But just four days before launch in 1971, a medical X-ray revealed a risk of tuberculosis in Kubasov. Although this was later found to be a misdiagnosis, the entire crew was grounded, as was the rule in those days, and the backup crew took their place. Naturally, Leonov and Kolodin were both livid with the decision.

But on 6 June 1971, Soyuz 11 took off with its back-up crew on what was to be a ground-breaking mission in space. The three cosmonauts would be the first - and only - crew to enter Salyut 1, the first ever space station to orbit Earth. Alongside this achievement, they also spent more than three weeks in space - more than any other astronauts or cosmonauts before them.

When the time came to undock and return to Earth on the evening of 29 June, spirits were high. But several hours later, in the early hours of the morning on 30 June, it was obvious something was wrong. Ground control was receiving no communication from the crew. The landing was entirely automated, so the capsule passed through the atmosphere and landed using parachutes in Kazakhstan by itself. As a recovery team made their way to the capsule, they were unaware of the horror that lay beyond the capsule door. All three of the crew were mysteriously dead. Attempts were made to resuscitate them, but to no avail.

Owing to the huge amount of secrecy in the Soviet space programme, the strange deaths of the cosmonauts sent shock waves not only through the Soviet Union, but through America, too. NASA, in the midst of its lunar missions, was unsure if prolonged spaceflight might have been the cause of death. The true cause would transpire later, though.

At an altitude of 130 kilometres (80 miles) and at around 1.47am Moscow time, the descent module that housed the astronauts of Soyuz 11 had separated from its orbital module. But somehow, the short procedure had ripped open an air valve on the descent module. The result was depressurisation. Air would have rushed out of the spacecraft and in a matter of seconds the three cosmonauts - who were not wearing spacesuits, as was procedure at the time - were exposed to the harsh, airless vacuum of space.

It's thought that the cosmonauts may have tried to locate the valve and close it. But within just 13 seconds, they would have lost any useful form of consciousness. After a minute, they would have been unconscious, coupled with a huge loss of blood, and death quickly followed. Alexei Leonov later demonstrated that closing the valve took 52 seconds, far longer than the cosmonauts had to act. The deaths of all three cosmonauts shocked the world, but no more so than in the Soviet Union where they had been lauded daily as heroes during their time in space.

A consequence of the mission is that all astronauts and cosmonauts now launch wearing a pressure suit, which can cope with depressurisation, although no such event has ever occurred since. A lasting memorial remains to the three space heroes on Pluto, where a group of hills was named Soyuz Colles in their honour. Dobrovolski, Volkov and Patsayev remain the only three humans to die in space. But their legacy, proving that long-duration spaceflight was possible, lives on.

Volkov, Dobrovolski and Patsayev (from left to right) inside the spacecraft simulator in 1971

© Getty Images

The BLUE MARBLE

In the last days of the Apollo era, astronauts captured one of the most influential images in human history

★ Written by Jackie Snowden ★

On 7 December 1972, the crew of Apollo 17 were well on their way to the Moon when they were treated to a rare sight. From their Command Module, some 29,000 kilometres (18,000 miles) away, astronauts Gene Cernan, Ron Evans and Jack Schmitt could see the entire sunlit face of planet Earth. Although they had strict schedules with mission-critical tasks to perform, fortunately one crewmember took a moment to capture the sensational view on film. The identity of the photographer remains a mystery - there was no reference to the photo being taken in mission communications and, retrospectively, each astronaut seemed sure they had been the one to take the shot. As per NASA policy, the image is credited to the entire Apollo 17 crew.

It wasn't until the mission returned and the photos were processed that the image's significance was revealed: this was the first full portrait of Earth anyone had ever seen. The dazzling photograph made the front page of newspapers all over the world. For the first time people could see the planet as it really is, without the divisions of political borders - just a fragile, almost iridescent 'blue marble' floating in an otherwise lifeless void. For many, the image evoked a much-needed boost to the sense of responsibility for our home. Its release seemed to coincide with the growing environmental awareness movements of the 1970s, and the Blue Marble image was fittingly adopted as the symbol of Earth Day.

Nearly five decades since its release, the Blue Marble continues to be one of NASA's most requested images. Little did the Apollo 17 crew know that one quick photo taken in a stolen moment would have such an enduring impact.

Blue Marble followed in the footsteps of Apollo 8's famous Earthrise photo, which captivated the public several years earlier

The Apollo 17 crew: Commander Eugene 'Gene' Cernan (front), Command Module pilot Ronald 'Ron' Evans (right) and Lunar Module pilot Harrison 'Jack' Schmitt (left) became the last men to travel beyond low Earth orbit

> “You have to literally just pinch yourself… when you can look out the window and you’re looking at the most beautiful star in the heavens – the most beautiful because it’s the one we understand and we know, it’s home, it’s people, family, love, life…”
>
> **Gene Cernan, Apollo 17 commander**

© NASA

TOGETHER AT LAST: THE APOLLO-SOYUZ PROJECT

How did a simple handshake in orbit end the Space Race?

★ **Written by Scott Reeves** ★

On 17 July 1975, Soviet cosmonaut Alexei Leonov stretched out his hand and held that of US astronaut Thomas Stafford. This simple act was more than a mere gesture of friendship; it was a moment as iconic as Neil Armstrong's first step on the Moon. Leonov and Stafford's handshake took place in orbit, high above the French city of Metz, and their greeting marked the moment that the Space Race came to an end.

The successful docking of American and Soviet spacecraft in the Apollo-Soyuz Project was the culmination of four years of scientific planning during a lull in Cold War tensions. Terrestrial diplomacy had moved on from the panic of the Cuban Missile Crisis. The Nixon administration had made clear its desire to extricate US forces from the Vietnam War, while Soviet Premier Leonid Brezhnev was prepared to negotiate face-to-face with US officials in an attempt to bring about military parity.

One of the watershed moments in the Cold War thaw known as détente occurred when US President Richard Nixon travelled to the USSR in May 1972 for the Moscow Summit. In a week of carefully choreographed negotiations and photo opportunities, Nixon and Brezhnev signed the SALT I and Anti-Ballistic Missile treaties and agreed new rules to prevent confrontations at sea. With such groundbreaking pacts being signed, it was easy to miss the Agreement Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes. It committed both countries to a joint space mission to design and test the Androgynous Peripheral Attach System (APAS), a module that would allow the Apollo and Soyuz spacecraft to dock together in space.

If the mission was to be a success, both American and Soviet engineers had to overcome deep-seated suspicions which had been established over decades. Some NASA scientists thought that the Soviet reliance on automation - with few manual controls that allowed cosmonauts to intervene and continue the mission if a component failed - was a sign that the Soyuz and those who flew in her were inferior to their American counterparts. It took quite an effort to persuade enough US Congressmen, many of whom were reluctant to promote cooperation in space, to part with the $245 million required to fund the Apollo-Soyuz Project. The Soviet Politburo was happy to fund its half of the mission, but Soyuz engineers viewed the complex Apollo spacecraft as a dangerous piece of kit flown by risk-taking, overconfident

STAFFORD
NASA
SLAYTON
BRAND

The American and Soviet crews visited their rival space programmes and were given a remarkable level of access

The handshake between Thomas Stafford and Aleksei Leonov is one of the most iconic moments in space exploration

WHO FINISHED THE SPACE RACE?

FROM THE FIRST SPACEWALKER TO THE OLDEST ASTRONAUT, MEET THE FIVE MEN WHO MARKED THE END OF THE COLD WAR IN ORBIT

Thomas Stafford

The most experienced person on the mission, Stafford was making his fourth and final flight into space. Stafford cut his teeth on Gemini 6A and Gemini 9 before trailblazing a path to the Moon on board Apollo 10, during which he flew the Lunar Module to within nine miles of the Moon's surface. Stafford was switched to fly on Gemini 9 after the mission's original two-man crew died in a plane crash.

Vance Brand

Brand was one of a select few astronauts who straddled two eras of exploration in space. The Apollo-Soyuz Project was Brand's first spaceflight, but he subsequently commanded three Space Shuttle flights in 1982, 1984 and 1990. By the end of his career he had spent more than 31 days in space. Brand was the only Apollo astronaut to fly aboard the Space Shuttle in the post-Challenger era.

Donald 'Deke' Slayton

Slayton was one of the original Mercury Seven batch of astronauts selected by NASA in 1957. However, he never got to fly with his contemporaries, grounded due to an irregular heart rhythm. He was shifted to a desk job in charge of the astronauts, but selected himself for the Apollo-Soyuz Test Project after being given medical clearance. 51-year-old Slayton was the oldest person to fly in space, though his crewmate Vance Brand would later fly at the age of 59.

Alexei Leonov

One of the initial cohorts of Soviet cosmonauts selected in 1960, Leonov became a genuine space pioneer on 18 March 1965 when he completed the first spacewalk, leaving the Vokshod capsule for just over 12 minutes. After the Apollo-Soyuz mission was complete he was appointed chief cosmonaut, overseeing crew training for the next six years.

Valeri Kubasov

Kubasov was extremely lucky that he had to wait an extra four years to make his second spaceflight. Already a veteran of Soyuz 6, he should have flown on the ill-fated Soyuz 11 with Alexei Leonov. However, Kubasov fell ill and his team was replaced by the backup crew, all of whom died when the spacecraft depressurised upon re-entering the atmosphere. Soyuz 6 was one of three manned Soviet flights in orbit at the same time.

BACK TO EARTH WITH A BUMP

HOW THE APOLLO-SOYUZ PROJECT NEARLY ENDED IN TRAGEDY

At the end of a successful mission, the Apollo-Soyuz Project nearly had a sting in its tail. Five days after undocking with the Soyuz for the final time, the astronauts aboard the Apollo module were ready to return to Earth, but it was during their atmospheric re-entry that the mission's only hiccup occurred. The astronauts endured a bumpy ride through the upper levels of the atmosphere, and as commander Thomas Stafford called out the re-entry checklist, Vance Brand didn't hear one of the items and forgot to close two crucial switches to turn off the reaction control system.

As the Apollo craft fell to Earth, unburned fuel from the system was vented from the spacecraft and entered the crew module through an air intake, causing Brand to pass out. Luckily Stafford realised that something was amiss and grabbed the emergency oxygen masks, putting one on his unconscious colleague while he and Deke Slayton donned their own. The Apollo splashed down as planned and the three astronauts were largely unharmed, although they did have an enforced two-week stay in hospital for observation. An eerie parallel with the Soyuz 11 disaster, where the cosmonaut crew suffocated as the Soyuz attempted re-entry, was narrowly avoided.

The sailors from USS New Orleans who were first to the Apollo splashdown nearly had the grisly job of retrieving the astronaut's bodies

> "Soyuz engineers viewed the complex Apollo spacecraft as a dangerous piece of kit flown by overconfident astronauts"

astronauts. However, suspicions were eased when engineers and crews were invited to train in the other's country, easing the mistrust that resulted from Cold War secrecy. Considering how closely both nations had previously guarded their technology, it was a remarkable act of openness.

After three years of preparation, the crews on opposite sides of the world readied for launch day on 15 July 1975. First to go was the Soyuz spacecraft, officially designated Soyuz 19, which launched from Baikonur Cosmodrome in Kazakhstan at 6:20pm local time. On board were commander Alexei Leonov and flight engineer Valeri Kubasov, both of whom were making their second spaceflight. Such was the publicity around the Apollo-Soyuz Project that it was the first time Soviet television carried a launch live – previous launches were only reported later by the media in case misfortune required state censors to step in.

Seven-and-a-half hours later – though at the earlier local time of 3:50pm due to time zone differences – a Saturn IB rocket departed from the Kennedy Space Center in Florida with a crew of three: commander Thomas Stafford, Command Module pilot Vance Brand and Docking Module pilot Donald 'Deke' Slayton. Once the Saturn had ejected its lower stage, the Apollo module separated from the upper stage and Brand manoeuvred it into a 180-degree turn. It then picked up the APAS module, which would allow the Americans to dock with the Soviets, and pulled away from the now-surplus rocket.

The next two days saw both crews make orbital adjustments until they were both on the same 229-kilometre (142-mile) high path around the Earth. As the distance between them slowly closed, Slayton controlled the course of the Apollo and attached the APAS module to the Soyuz. The two spacecraft from rival superpowers were now locked together. Three hours and five minutes later the crews opened the airlock between them, and Stafford and Leonov floated towards each other for their momentous handshake.

The rest of the afternoon was spent marking the symbolic moment. The now five-man crew exchanged flags and gifts, including tree seeds which were later planted in each country, and signed commemorative certificates. They took calls from US President Gerald Ford and Soviet leader Brezhnev and enjoyed a communal dinner before retreating to their own spacecraft to sleep. Both astronauts and cosmonauts awoke the next morning with a tight schedule to get through a busy day. Some time was dedicated to science, with the crews conducting experiments, but some was spent continuing the diplomatic effort. After filming in both spacecraft the astronauts and cosmonauts split up, with Kubasov joining Brand and Slayton in the Apollo while Leonov and Stafford worked in the Soyuz.

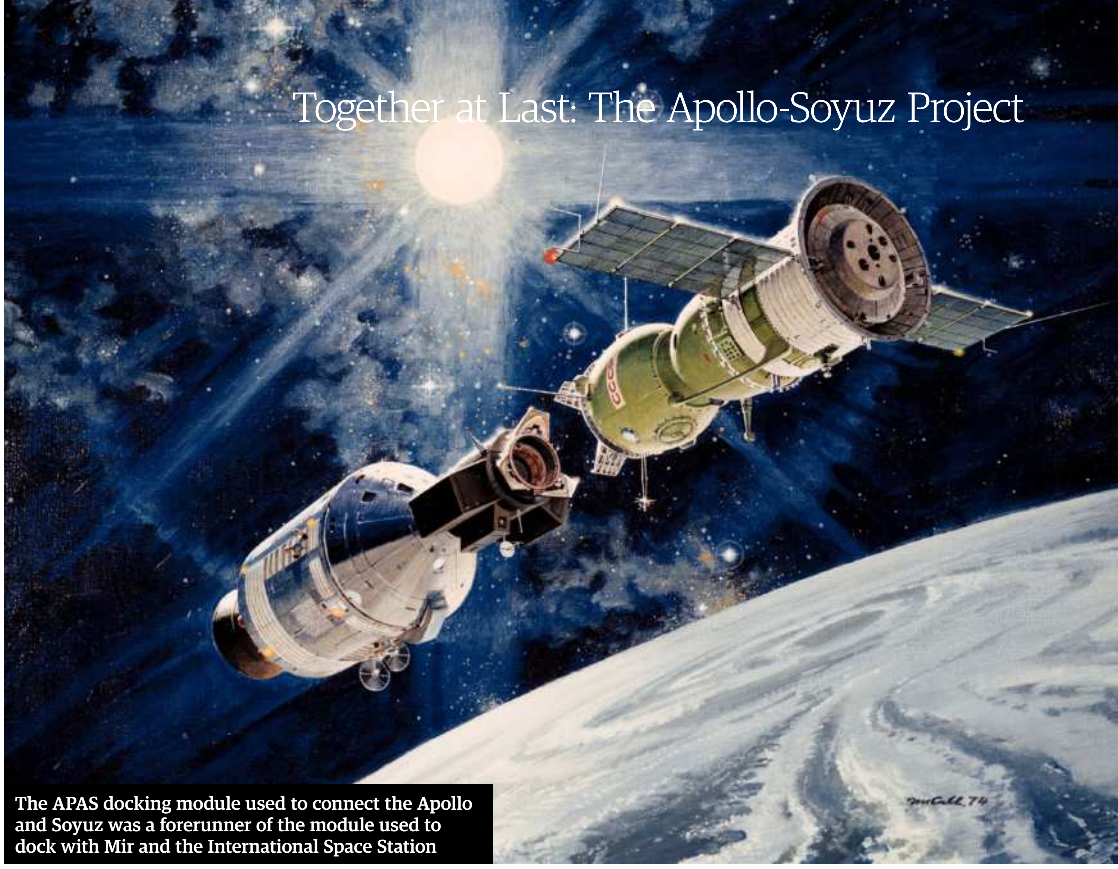
Come the evening the two crews shook hands for the final time and returned to their own modules, closing the hatch between them. At 12:02pm GMT on 19 July the spacecraft separated and the Apollo manoeuvred in front of the Sun, creating an artificial eclipse so the cosmonauts on board the Soyuz could take photographs of the Sun's corona. The Soyuz then re-docked with the Apollo in a further test of the APAS module, but the hatch between them remained closed. At 3.26pm GMT the Apollo and Soyuz separated again, never to be rejoined in space.

Both spacecraft remained in orbit to conduct further experiments before returning to Earth. The Soyuz landed in the early morning of 21 July near Baikonur Cosmodrome; the Apollo splashed down in the Pacific on 24 July. It marked the official end of the Apollo Applications Program, an extension to the original Apollo Program which ran from 1961 to 1972. Not for another six years would NASA launch a manned spaceflight, when the first Space Shuttle mission reached orbit on 12 April 1982. The Apollo modules that carried astronauts to orbit and back

Both President Ford and Leonid Brezhnev spoke to the crews, using the mission as a diplomatic tool

Richard Nixon and Alexei Kosygin signed the Apollo-Soyuz agreement on the fringes of the Moscow Summit of May 1972

The Apollo-Soyuz Project was the last time the Saturn rocket and Apollo module would be used in spaceflight



The APAS docking module used to connect the Apollo and Soyuz was a forerunner of the module used to dock with Mir and the International Space Station

SLAYTON
NASA
APOLLO/SOYUZ

The effects of zero-gravity allowed Deke Slayton and Aleksei Leonov to share an unusual embrace

were relegated to museum pieces - the one used in the Apollo-Soyuz Project remains on display at the California Science Center in Los Angeles.

The Apollo and Soyuz spacecraft may only have been attached for 47 hours, but the mission had a long legacy. Scientific cooperation across the Cold War divide had been proven to work, and leaders at NASA and the Soviet space agency began to discuss future missions together. Proposals included the American Space Shuttle flying to the Soviet Salyut space stations, or a mission involving the Soviet Buran shuttle docking with a planned, but ultimately never built American space station. However, no joint projects got beyond the drawing board, as events on Earth interfered with those in orbit.

In 1979 Soviet troops moved into Afghanistan and the Cold War détente that allowed the Apollo-Soyuz Project to take place came to an end. Tensions increased throughout the 1980s, with NATO's Able Archer exercises nearly causing a pre-emptive Soviet strike in 1983 and Ronald Reagan's combative rhetoric making it difficult to justify cooperative action. However, the sudden collapse of the USSR in 1991 allowed NASA and Roscosmos - the Russian successor to the Soviet space agency - to resume negotiations. The four-year Shuttle-Mir Program began in 1994 and saw American astronauts spend lengthy periods on the Russian space station, while Russian cosmonauts flew aboard the Space Shuttle. On 2 November 2000, the first multi-national crew of one American and two Russians arrived aboard the International Space Station, marking the beginning of the next era of international cooperation in space.

The friendships formed in space on the Apollo-Soyuz Project have also endured. Leonov and Stafford, the two commanders who shared the first handshake through the APAS module, stayed in touch throughout the final years of the Cold War. When Stafford adopted two boys in his sixties, he asked Leonov to be their godfather.

As the leader of the USSR between 1964 and 1982, with the ability to launch nuclear strikes at the mere push of a button, Leonid Brezhnev knew how easily the Cold War could have turned hot. He also knew that cooperation in space through the Apollo-Soyuz Project would give astronauts and cosmonauts a unique perspective on the ideological war raging back down on Earth: "They know that from outer space our planet looks even more beautiful. It is big enough for us to live peacefully on it, but it is too small to be threatened by nuclear war." The end of the Space Race may not have ended the Cold War on Earth, but it was a clear sign that the future of the superpowers from opposite sides of the world lay in good-intentioned cooperative missions, rather than deadly combative missiles.

Docking with the Soyuz - seen here from the Apollo - required Deke Slayton to pilot the American craft with great accuracy

© All images NASA

What if...

THE SOVIETS HAD WON THE SPACE RACE?

THE SPACE RACE – SOVIET UNION VS THE USA, 1957 - 1969

★ Written by Jonathan O'Callaghan ★

DR CHRISTOPHER RILEY

Dr Riley is a writer and filmmaker who specialises in science, space, engineering and history. He has worked on numerous documentaries including *In The Shadow Of The Moon*, *First Orbit* and *Neil Armstrong – First Man On The Moon*. You can follow him on Twitter @alifeofriley.

What if the Soviets had won the space race?
I think they would have perhaps established some kind of permanent lunar base in the way they colonised Earth orbit [in the Seventies and Eighties]. It might have been that they continued to run with a presence on the Moon instead of just sort of going there for a few days and coming back and then never returning, as essentially what has happened now. However, you've got to imprint upon the effect that the break up of the Soviet Union had on the space programme. That really caused a massive underinvestment, which might have ultimately led to any lunar base being abandoned - and we'd be back where we are today.

Did the successful launch of the Soviet Union's Sputnik 1 in 1957, the first man-made satellite in space, inspire America to reach for the Moon?
Oh yes, undoubtedly. The 'Sputnik effect', as it's called, was a significant player in ensuring that Apollo succeeded. President Eisenhower commissioned the Saturn V rocket and he boosted brainpower by investing in universities. I think Apollo made America smarter for that period - and the legacy of that was, of course, not just to win the Moon race but the spin-offs that happened. Not least the micro-computing processing revolution and ultimately the Internet, of which the early DARPA [Defense Advanced Research Projects Agency] structures were the forerunner, as they were all wrapped up in the Cold War investments the government had made. We've got our modern society to be thankful for because of that initiative, that 'Sputnik effect'. We're still living off that. It was profound, what Eisenhower did.

When was the moment that the United States took the lead in the space race?
The Zonds [Soviet spacecraft] were racing around the Moon unmanned in 1968, so I think you have to point to Apollo 8 [in December 1968], which was this very audacious and perhaps even somewhat reckless mission to pull off. Apollo 8 was previously just an Earth orbit mission, but they instead went straight [around] the Moon on the first Saturn V launch, which was a very, very brave thing to do. Ultimately that bravery, that gamble that they somehow managed to pull off, was the turning point without a doubt.

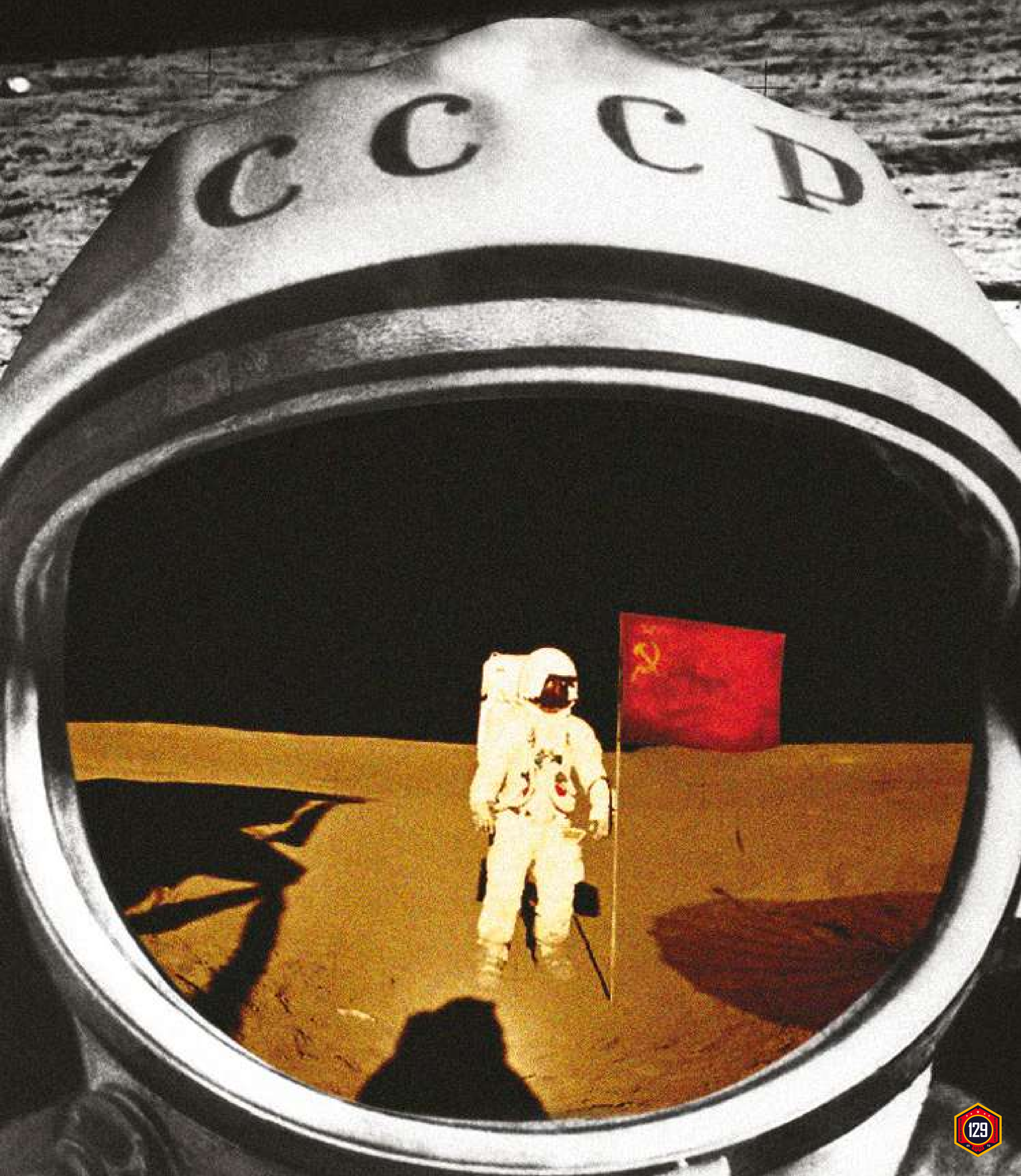
Was there any other major turning point that happened during the space race?
The N1 disaster [the Soviet Moon rocket that failed five times] was obviously a colossal setback. But it wasn't just about booster technology; the Russians easily matched the Saturn V, they were ahead in booster lift for many years. But the clincher was the computing power, that is where the Russians were really falling short.

How far behind were the Russians in terms of their computing power?
While the Russians might have been able to orbit the Moon, it was a far cry from landing on it. The thing that really clinched the success of Apollo, in no uncertain terms, was their computing power. The fact that NASA had invested significant amounts of money in the manufacturing of integrated circuits in order to create the micro-computers that were light and small enough to be able to fly on these [Apollo] spacecraft, and make these precise landings on the Moon. The Russians, as far as I'm aware, didn't really have that sort of micro-processing capability in those days. Their systems probably wouldn't have allowed them to really make a successful landing. It wasn't impossible, but it was quite unlikely.

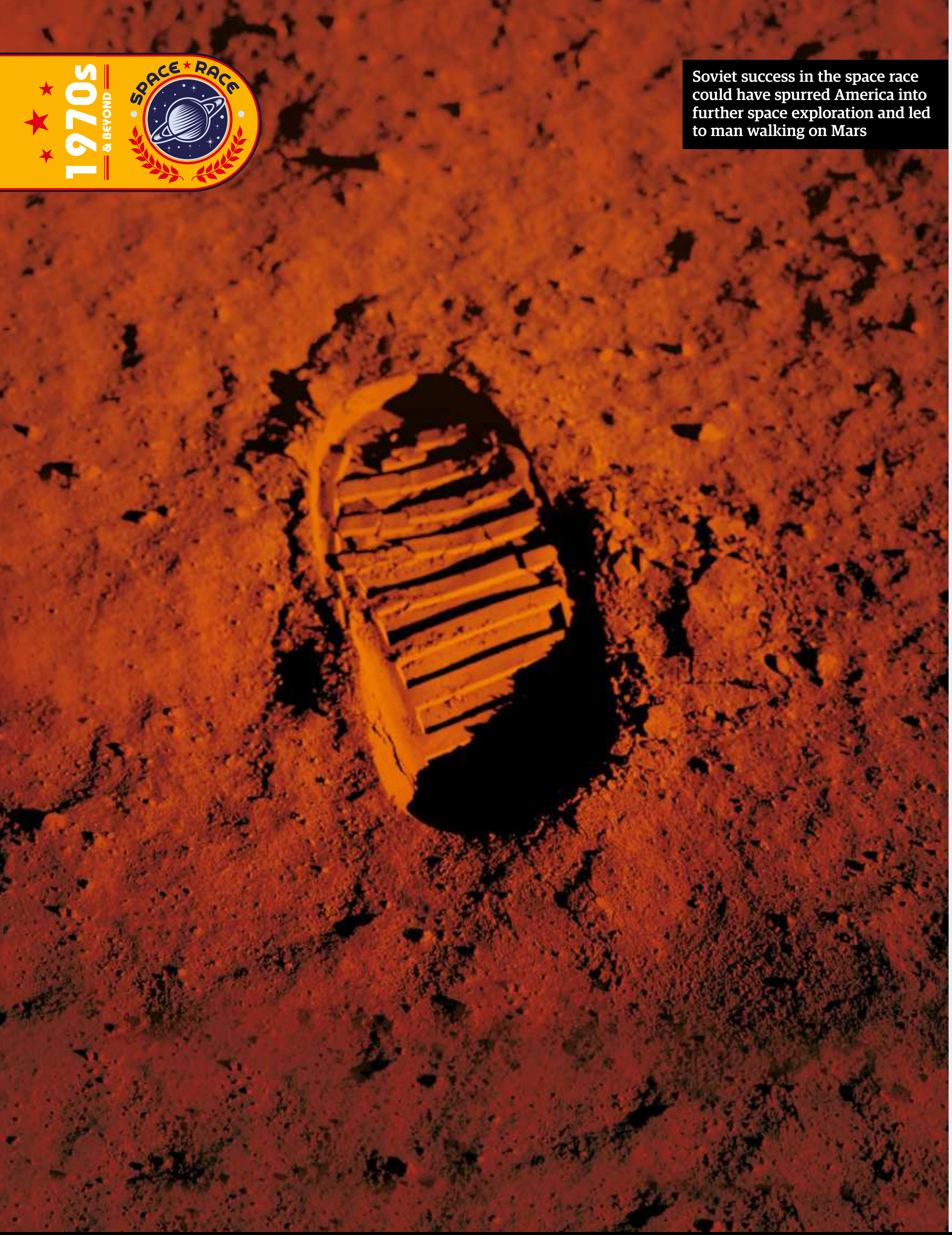
Did the Soviets realise this?
I think they were just sort of gambling on the judgement of their pilots and hoping they could pull it off without this computing power. The Russian approach to spaceflight in the Sixties, both robotic and human, was a little bit of fingers firmly crossed behind your back as they launched. Everybody needed an element of luck; luck goes hand in hand with skill and engineering when it comes to spaceflight, of course. But the Russians relied on luck a bit more, and the reason I say that is because they essentially ran for all these very quick firsts in human spaceflight in the Sixties. For example, they were the first to put three people in a capsule, and they only did that by depriving them of their pressure suits so they could squeeze them into a two-man capsule. Things like that were clearly a bit reckless with the way they went forward. While they probably were aware that their computing power was inferior to the Americans, I think they just thought they'd wing it and their pilots would hopefully be able to pull [a lunar landing] off just manually.

If they had landed first, how would it have changed the Soviet Union as a whole?
Well you've got to look at how they reacted to

What if the Soviets had won the space race?



With better computer power the Soviets could have won the space race and put a man on the moon



Soviet success in the space race could have spurred America into further space exploration and led to man walking on Mars

> "They would have perhaps established some kind of permanent lunar base"

Gagarin returning [in April 1961] and Valentina Tereshkova [the first woman in space in June 1963] and the other heroes of spaceflight that placed Russia so high on the world stage. I think a successful returning lunar cosmonaut would have been celebrated and lauded around the world in exactly the same way. If you look at the 'Giant Step' tour that the crew of Apollo 11 went on in the summer of 1969 when they got back, 40 countries in 30 days or something like that, touring the world with millions of people coming out on the street and giving these ticker tape parades wherever they went, you can imagine that absolutely would have happened to the Russians as well. Whether it would have had a material change on the course of Russian history and how their society changed in the Eighties and Nineties, I don't know. It would have been great when it happened in the Sixties, but perhaps it wouldn't have made a big difference in the grand scheme of things.

Which Soviet cosmonaut do you think might have taken the first steps on the Moon?

Alexei Leonov's name often comes up as the first Moon walker, having done the first spacewalk [in March 1965] and contended with those difficulties and survived the mission. I think he likes to think he would have been as well from

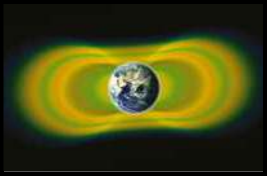
HOW WOULD IT BE DIFFERENT?

REAL TIMELINE

1957

FIRST ARTIFICIAL SATELLITE IN SPACE
To the shock of the United States and the wider world, the Soviet Union successfully launches an unmanned satellite, known as Sputnik 1, into space.
4 October 1957

EXPLORER 1
America strikes back at the Soviet Union with its own artificial satellite, Explorer 1. This satellite then discovered the Van Allen radiation belts that surround Earth.
31 January 1958



EISENHOWER BOOSTS BRAINPOWER
In a bid to prevent the US from falling behind the Soviet Union, President Eisenhower introduces the National Defense Education Act (NDEA) to increase education funding.
2 September 1958

FIRST HUMAN IN SPACE
The Soviets get another first, this time sending the first human into space, Yuri Gagarin, just weeks before the US launches their own Alan Shepard.
12 April 1961

SATURN V LAUNCHES
NASA's huge Saturn V rocket that will be used for the Apollo missions passes its first test flight with flying colours.
9 November 1967

APOLLO 8
NASA must make a decision whether to send Apollo 8 on a manned or an unmanned flight around the Moon.
1968

REAL TIMELINE

MANNED APOLLO 8 LAUNCHES
The three-man crew of Apollo 8 successfully launches and orbits the Moon, paving the way for a manned lunar landing.
21 December 1968

ALTERNATE TIMELINE

UNMANNED APOLLO 8 LAUNCHES
The US launch Apollo 8 as an unmanned mission, delaying any eventual manned lunar landing, and allowing the Soviets to catch up.
21 December 1968

his writings and interviews since – and I dare say he's right.

Would they still have proclaimed the Moon 'for all mankind' as the Americans did?

If you listen to Khrushchev's speeches at the time, they were all about how Gagarin's flight was for everybody. The whole point was it was a gift to the world and it was Russia's great gift to human history, so they would have, I'm sure, done the same thing [on the Moon]. Whether they'd have taken a UN flag, which was proposed initially for the Americans to fly rather than the stars and stripes, or whether they'd have planted their own hammer and sickle I don't know. I suspect they would have planted their own flag, but their speeches and plaques that they unveiled I'm sure would have had the same sentiments [as Gagarin's flight].

What might their first words on the Moon have been?

Well, [Neil] Armstrong was given complete freedom, as were all of the previous crews of Apollo 8. They decided what they would read or speak, and no one intervened. In fact, while Armstrong had obviously given it a lot of thought, he had a number of options from what his mother told me last year and he made his final decision as to what was going to be said when he was going down the ladder. I think with the Russians, knowing a bit about how their society worked at the time, it would have been very carefully written. There's a speech that Gagarin makes before he climbs in the rocket [on the first spaceflight in April 1961] and it's beautifully and poetically sculpted in terms of its message to the world, and it was completely written for him by the central government. I think it would have been a similar sort of speech that would have been written for the first lunar cosmonaut.

Do you think a successful lunar landing would have prevented the collapse of the Soviet Union?

No, I don't. If you look at what it did to America, they won this race and very quickly the country got sick of spending money, and within a few missions after Apollo 11 the programme was cancelled. The political direction afterwards, both in positive and negative terms, was not really influenced by the success of Apollo, perhaps sadly. So I suspect in Russia it would have been exactly the same. They would have had this time that they carried on running their bases, maybe on the Moon as we've talked about, certainly building a space station in Earth orbit, until effectively politics and perhaps society and the rest of the world overwhelmed them.

Would the USA have tried to one-up the Soviet Union by attempting to go to Mars?

It's nice to imagine that the race could have hurdled us down the Solar System to further away, and there's some sort of validity in that the Cold War had continued to sabre-rattle its way into the Nineties. Would America have gone even further to prove a point? It's possible. Remember Spiro Agnew, the vice president at the time Apollo 11 left for the Moon, said they were going to be on Mars by 1980! So there were plenty of plans; [American rocket scientist] Wernher von Braun's bottom draw had loads of concepts in it for adapting and modifying Apollo configurations to send them further. It's a lovely thought to imagine that with Apollo hardware, you could have actually had a human footprint on Mars by now.

Would they have succeeded?

I don't know. I mean, it took four million human years to put those 12 Americans on the Moon – the work of 400,000 people for a decade. I think you could have multiplied that by 100, maybe 1,000, to land on Mars. It would have been very difficult to do, and it still remains so.

How would modern space exploration be different if the Soviets had been first on the Moon?

If – and this is an enormous if, and not one I think likely – the Russians had got to the Moon first and the Americans had gone to Mars, we would have skipped the space station stage as it were. The [International Space Station] was largely conceived and built to justify the Space Shuttle, so we probably wouldn't have gone down that route. We would have just been pushing the frontier of human footprints across the Solar System. I think if we'd gone as far as then changing this mindset from racing to collaborating as a community, we'd again be looking at a sort of equivalent to the space station – a laboratory, but somewhere on the Moon or Mars instead, rather than in Earth orbit. It would have ultimately been a completely different picture from the years of shuttle flights and space stations that we've lived through instead.

> "It's nice to imagine that the race could have hurdled us down the Solar System further away"

THE SOVIETS FALL BEHIND

The Soviet Union's answer to the Saturn V, the N1 rocket, explodes on its first launch and fails a further three times by 1972.

21 February 1969

A GIANT LEAP FOR MANKIND

Neil Armstrong and Buzz Aldrin become the first humans to set foot on the Moon on the Apollo 11 mission, winning the space race for the US. Five more occur by 1972.

20 July 1969

SPACE STATIONS

By the Eighties both the United States and Soviet Union (later Russia) have focused much of their efforts on space stations and missions to Earth orbit.

1980

INTERNATIONAL SPACE STATION

The US, Russia and other nations continue to collaborate and operate the International Space Station in Earth orbit, but no humans have ventured further since 1972.

2013

SOVIETS AIM FOR THE MOON

Buoyed by the stagnation in the American lunar programme, the Soviets ramp up their efforts to send humans to the Moon, culminating in a successful test of their N1 rocket.

1969

SOVIET LANDING

While the US debates the future of Apollo, the Soviets stun the world again by sending a single cosmonaut, Alexei Leonov, on a daring mission to the lunar surface, from which he returns a hero.

July 1969

AMERICA SHOOTS FOR MARS

Still reeling from the Soviet space race victory, America attempts to one-up the Soviets, announcing their intentions to land humans on Mars. They ultimately succeed in doing this in 1980.

1970

SPACE COLONISATION

After four decades of exploration – and thanks to the collapse of the Soviet Union – the US, Russia and other nations collaborate on human exploration endeavours throughout the Solar System.

2013

© Nasa, Corbis

WHO REALLY WON THE SPACE RACE?

Those all-important first steps on the Moon were American, but the Soviets also made many giant leaps

Written by Jacqueline Snowden

In 1961, the USSR were well and truly leading in the Space Race. The Soviets had beaten the Americans at every major spacefaring achievement, and President Kennedy knew that it would take an audacious plan to turn the tide in America's favour. In May that year, he announced the goal of putting man on the Moon by the end of the decade.

America's gambit paid off. The success of the Apollo 11 mission was the defining Space Race victory, overshadowing many of the Soviets' (and America's own) triumphs that came before and after. In terms of individual achievements, however, the race was not as clear-cut as you might think. Take a look below to see the unexpected successes and failures of the Space Race.

USA

SECOND PLACE

FIRST COMMUNICATIONS SATELLITE

The top-secret Project SCORE was disguised as a routine missile test. Instead, it launched a satellite that broadcast President Eisenhower's pre-recorded Christmas message to the world.

18 DECEMBER 1958

FIRST PHOTOS OF EARTH FROM SPACE

In 1946, America began a series of launches using modified V-2 rockets captured from the Nazis. One of these test launches captured the first images of Earth from space.

24 OCTOBER 1946

FIRST INTERPLANETARY MISSION

After several failed missions by both the US and USSR, the Mariner 2 probe made the first successful flyby of Venus, collecting data on the planet's unusual atmosphere.

14 DECEMBER 1962

FIRST SUCCESSFUL MARS MISSION

The USSR had launched several failed Mars flyby missions before NASA's second attempt – Mariner 4 – succeeded. It also took the first photographs of another planet from space.

15 JULY 1965

USSR

FIRST PLACE

FIRST ARTIFICIAL SATELLITE

The successful launch of Sputnik 1 was the first victory of the Space Race. It was a shock to America, who assumed they had the technological upper hand against the Soviets.

4 OCTOBER 1957

FIRST MAN IN SPACE

Yuri Gagarin orbited Earth aboard Vostok 1, becoming the first human in space. The project was a secret rival to America's Project Mercury, which launched Alan Shepard into space just 23 days later.

12 APRIL 1961

FIRST WOMAN IN SPACE

Cosmonaut Valentina Tereshkova became the first woman in space aboard the Vostok 6 orbital mission, 20 years before American Sally Ride became NASA's first female astronaut on the STS-7 Shuttle mission.

16 JUNE 1963

FIRST SPACEWALK

Alexei Leonov left his Voskhod 2 capsule for 12 minutes and completed the first spacewalk three months before his American counterpart, Ed White, made the second.

18 MARCH 1965

REST OF THE WORLD

While the US and the USSR battled for space superiority, other nations began to launch programs of their own

UK

THIRD COUNTRY TO OPERATE A SATELLITE

Following an invitation by NASA to assist with other nations' space ambitions, the UK proposed the design of Ariel 1, a satellite to study Earth's ionosphere and solar radiation. Construction was shared between the UK and US, and Ariel 1 launched from Cape Canaveral in Florida aboard an American Thor-Delta rocket.

26 APRIL 1962

UK'S FIRST INDEPENDENT SATELLITE LAUNCH

Prospero was the UK's first satellite sent into orbit using a British rocket. It launched from a Royal Air Force base in Woomera, Australia, aboard a Black Arrow rocket, and was used to test out instruments that could be used for communications satellites.

28 OCTOBER 1971

CANADA

FOURTH COUNTRY TO OPERATE A SATELLITE

Canada's Alouette 1 was the first satellite to be designed and built by a country other than the Space Race superpowers. It was constructed by a team at the Canadian Defence and Research Telecommunications Establishment (DRTE) and launched aboard the US's Thor-Agena rocket at the Vandenberg Air Force Base in California.

29 SEPTEMBER 1962

FIRST SUCCESSFUL SPACECRAFT DOCKING

Commander Neil Armstrong led the Gemini 8 mission to dock with an unmanned target vehicle while in orbit. The Soviets achieved the first automated docking 19 months later.

16 MARCH 1966

FIRST MANNED FLYBY OF THE MOON

Apollo 8 was the first manned mission to visit the Moon. The crew entered lunar orbit on Christmas Eve and made ten orbits before safely returning to Earth.

24 DECEMBER 1968

FIRST MAN ON THE MOON

Often considered to be the defining victory of the Space Race – when Neil Armstrong left the Apollo 11 lunar lander he became the first person to set foot on another world.

20 JULY 1969

FARTHEST HUMANS FROM EARTH

While flying past the far side of the Moon, the Apollo 13 crew ventured further from Earth than anyone had before. That record of 400,171 kilometres (248,655 miles) still stands today.

15 APRIL 1970

FIRST MISSION TO THE OUTER PLANETS

Pioneer 10 was the first mission to visit the gas giant Jupiter, and became the first man-made object to travel fast enough to leave the Solar System.

3 DECEMBER 1973

FIRST SPACE TELESCOPE

America's Orbiting Astronomical Observatory 2 (OAO-2) was the first successful space-based telescope. It launched three years before the USSR's Orion 1 observatory, which was installed on Salyut 1.

7 DECEMBER 1968

FIRST VENUS LANDER

Venera 4 was the first successful probe to reach the surface of Venus, managing to return data about the planet's atmosphere during its descent.

18 OCTOBER 1967

FIRST ROVER

The Soviets' Lunokhod 1 was the first rover to operate beyond Earth. The remotely controlled probe analysed lunar soil samples and took photos.

17 NOVEMBER 1970

FIRST SPACE STATION

The USSR launched the world's first space station, Salyut 1. It would be another two years before NASA followed suit with the launch of the Skylab research station in 1973.

19 APRIL 1971

FIRST UNMANNED MOON MISSIONS

The Luna probe program achieved many firsts at the Moon: Luna 2 reached the surface, Luna 3 photographed its far side, Luna 9 made a soft landing, and Luna 10 entered lunar orbit.

14 SEPTEMBER 1959 (LUNA 2)
7 OCTOBER 1959 (LUNA 3)
3 FEBRUARY 1966 (LUNA 9)
3 APRIL 1966 (LUNA 10)

FIRST OBJECTS ON MARS

Although the landers themselves failed, the identical Mars 2 and Mars 3 probes became the first human-made objects to reach the surface of the Red Planet.

27 NOVEMBER 1971 (MARS 2)
2 DECEMBER 1971 (MARS 3)

ITALY

FIFTH COUNTRY TO OPERATE A SATELLITE

The San Marco 1 was Italy's first satellite, successfully launched in cooperation with NASA. It carried instruments to study the Earth's upper atmosphere, and was launched aboard an American Scout rocket from Wallops Island in the US. NASA also trained the Italian ground crew to launch the rocket.

15 DECEMBER 1964

FRANCE

THIRD COUNTRY TO LAUNCH THEIR OWN SATELLITE

France became the third spacefaring nation on their own merit with the launch of the Astérix satellite aboard a Diamant A rocket from the Hammaguir launch site in Algeria. Although the UK, Canada and Italy had successfully sent satellites into orbit before the French, theirs were all launched aboard American rockets.

26 NOVEMBER 1965

ESTABLISHED THE KOUROU LAUNCH SITE

In the 1960s, the French National Space Agency (CNES) established the Kourou launch site in French Guiana, which became operational with its first launch in 1968. Today, the Guiana Space Centre is shared between CNES and the European Space Agency (ESA), and is used to launch the ESA's Ariane rockets.

9 APRIL 1968

JAPAN

FOURTH COUNTRY TO LAUNCH THEIR OWN SATELLITE

The successful launch of the Ohsumi made Japan the fourth country to send a satellite into orbit without help from another nation. Ohsumi was also one of the first satellites to be made purely for academic research purposes. It was launched aboard a Lambda rocket from what is now the Uchinoura Space Center.

11 FEBRUARY 1970

CHINA

FIFTH COUNTRY TO LAUNCH THEIR OWN SATELLITE

China launched their first satellite, Dongfanghong 1, aboard a Long March 1 rocket from the Jiuquan Launch Center in the Gobi desert. Dongfanghong, or "The East Is Red", was the name of a song that became an anthem of the People's Republic of China in the Sixties.

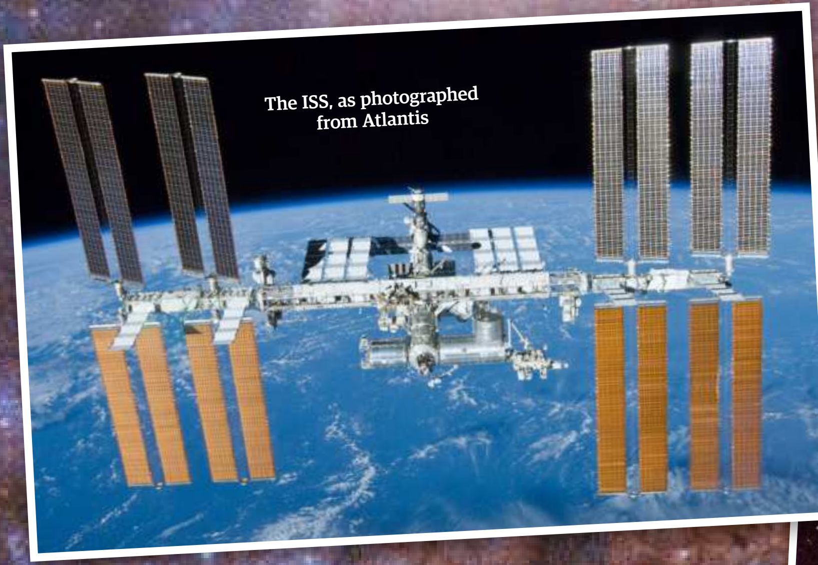
24 APRIL 1970

© Getty Images

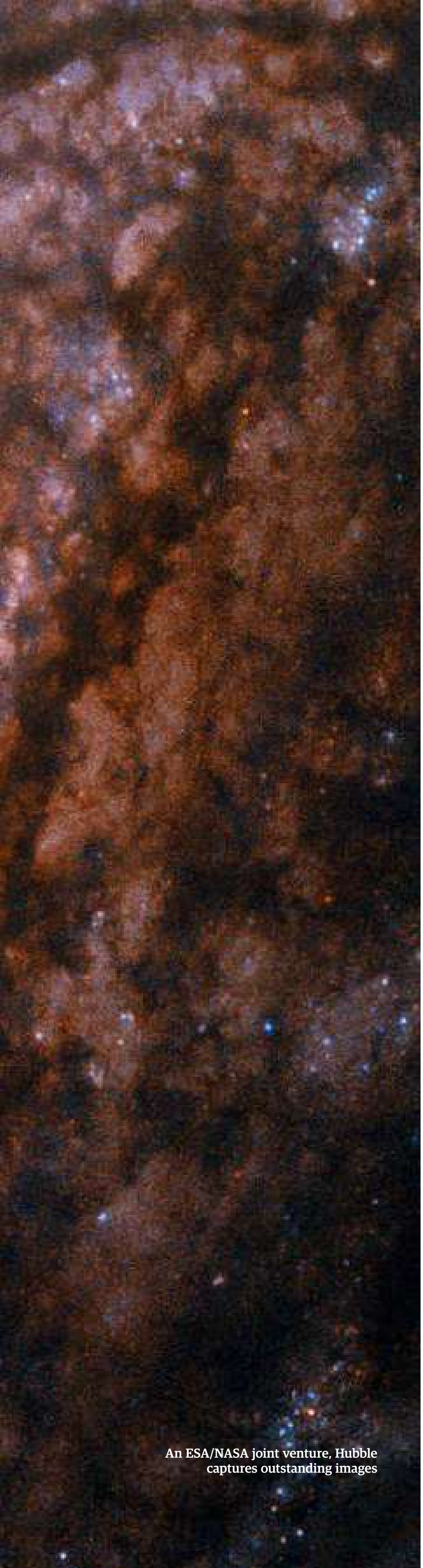
AFTER the FINISH LINE

The end of the Space Race welcomed decades of exploration and cooperation

★ Written by Nikole Robinson ★


The ISS, as photographed from Atlantis

There was a combined international effort to collect data on Halley's Comet



An ESA/NASA joint venture, Hubble captures outstanding images

A little competition is healthy, even if you are tiptoeing the line of nuclear war. Tensions ran high between the US and the Soviet Union until the mid-1970s, as each superpower tried to outperform its rival in showing off technological prowess, each wishing to proclaim dominance over space – and the other. These displays of power and their competitive nature spurred on many firsts in exploration during a short period. Satellites were launched and probes were sent to the Moon, Mars and Venus, opening up a little more of our Solar System for all of humanity.

The leap to this new frontier prompted a need for legislation to ensure that space didn't become a warzone. After years of discussion the Outer Space Treaty was entered into force by the UN in 1967, stipulating that the exploration of outer space should be done to benefit all countries and limiting the use of celestial bodies to peaceful purposes. This treaty has been developed along with the evolution of spaceflight, and today 108 countries are party to it, while another 23 are awaiting ratification.

Two years after the treaty was signed, the Space Race began to wind down once American boots walked on the surface of the Moon. The USSR re-evaluated its position in space and instead focused on research into Earth-orbital space stations, launching Salyut 1 in April 1971. The two powers would come together in 1972 to plan work on a joint Apollo-Soyuz test project, ending years of near-hostility and opening a dialogue on how they could further their knowledge together. Kennedy had originally proposed collaboration over competition in 1963, but this fell through after his untimely and unexpected assassination.

> "NASA was developing a reuseable spacecraft"

The Space Race dissolved, so both countries were happy to share experience and expertise with countries looking to develop space programmes, the USSR designing the Interkosmos programme to help its allies with space missions. This project saw the first citizen of a country outside the US or USSR – Vladimir Remek of Czechoslovakia – visit space; within ten years this venture produced 14 non-Soviet cosmonauts who participated in Soyuz space flights from countries such as Vietnam, India, Cuba and even capitalist France and Austria. These missions had another benefit in strengthening Soviet relations with the participating nations.

Meanwhile NASA was developing a reuseable spacecraft, which would materialise as the Space Shuttle. It had also sent Helios-A and B to the Sun alongside West Germany and worked with the European Space Agency (ESA) on the International Earth-Sun Explorer missions and the International Ultraviolet Explorer observatory. The ESA itself was a by-product of the Space Race: fearing their

SPACE NATIONS

TECHNOLOGICAL ADVANCES MEAN SEVERAL COUNTRIES ARE NOW AIMING FOR THE STARS

JAXA

JAPAN

Japan is yet to achieve human spaceflight as a nation, but Japanese astronauts have flown on various Space Shuttle and Soyuz missions. Japan is currently conducting a sample-return mission on the asteroid Ryugu.

CNSA

CHINA

With the 2003 flight of Shenzhou 5 carrying Yang Liwei, China became the third country to independently achieve human spaceflight. China is looking to establish a permanent space station in 2020 and send humans to the Moon.

ISRO

INDIA

While India's first satellite Aryabhata was launched by the USSR in 1975, in 1980 it launched Rohini using the ISRO-developed Satellite Launch Vehicle. ISRO was the fourth agency to reach Mars orbit with Mangalyaan in 2014.

Israel Space Agency

ISRAEL

Israel has a long history of launching its own satellites, beginning in 1988 with Ofeq-1. The agency invested heavily in SpaceIL's Beresheet, which would have made Israel the fourth nation to land on the Moon – however, due to possible engine failure, it crashed into the surface on arrival in April 2019.

Korea Aerospace Research Institute (KARI)

SOUTH KOREA

Yi So-yeon was the first Korean astronaut in 2008 via the Russian space programme after training at the Yuri Gagarin Cosmonaut Training Center near Moscow. KARI is currently developing its own launch vehicles.

Mohammed Bin Rashid Space Centre

UNITED ARAB EMIRATES

A country rich on oil, the UAE is looking to invest its wealth in space travel with a planned Mars probe, the Hope Mars Mission, set for 2020. This mission would make the UAE the first Muslim-majority country to head for Mars.

SPACE INNOVATIONS

TEN TECHNOLOGIES TO THANK SPACE EXPLORATION FOR

1. SMARTPHONES

Today's phones are more powerful than the computers used to take humans to the Moon. Digital image sensors found in camera phones are a result of NASA's desire for compact cameras.

2. ARTIFICIAL LIMBS

NASA innovations in robotics and shock-absorption materials are being applied by many private companies in the development of functionally dynamic prostheses.

3. SMOKE DETECTORS

Smoke detectors already existed, but NASA developed a more modern version with adjustable sensitivity as part of the Skylab project.

4. LAPTOPS

NASA flight computers need to be compact but powerful, and technological advancement means capabilities are always increasing. Computer mice were also a NASA development.

5. SCRATCH-PROOF LENSES

Researched to improve the visibility of astronauts' helmet visors, as well as other surfaces in space, scratch-resistant lenses are used on eye glasses today.

6. WATER PURIFICATION

NASA designed a silver iodiser in the 1960s to purify astronauts' drinking water. It is still researching this field heavily today in preparation for far-reaching human space exploration.

7. MEMORY FOAM

Memory foam was the result of development in the 1970s to improve the comfort and safety of aircraft seats. It was also implemented in the Space Shuttles.

8. WIRELESS HEADPHONES

Using hands-free technology allows astronauts to communicate effectively while busy at work. These are also useful to many other professions and for entertainment.

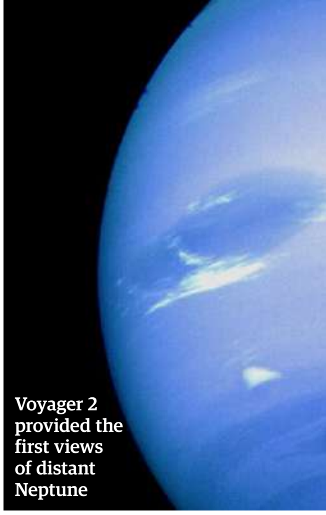
9. FREEZE-DRIED FOOD

Extensive research into space food found a way of freeze-drying food so it retains 98 per cent of the nutrients but typically only weighs 20 per cent as much, very useful for storage and preservation.

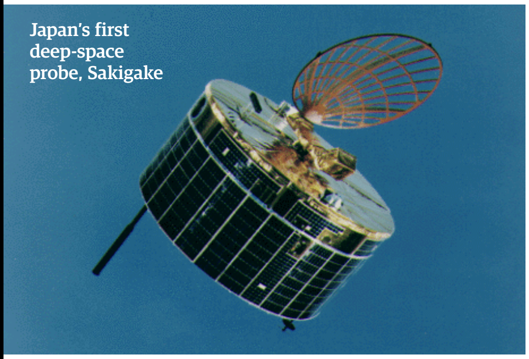
10. FOIL HEAT-TRAPPING BLANKETS

Often found as part of a first-aid kit and used in disaster relief, these lightweight insulated blankets reflect infrared radiation and were developed as part of the space programme in 1964.

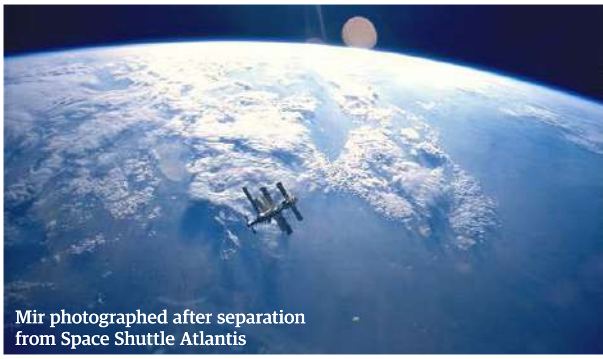
NASA's Robert Gibson and the USSR's Vladimir Dezhurov meet as Mir docks with the Space Shuttle



Voyager 2 provided the first views of distant Neptune



Japan's first deep-space probe, Sakigake



Mir photographed after separation from Space Shuttle Atlantis

countries alone couldn't compete with the reigning superpowers, several representatives from Western European nations met to discuss a proposed joint agency. Two agencies were formed, the European Launch Development Organisation, focused on developing a launch system, and the European Space Research Organisation. These merged in 1975 following the ESA Convention, with ten original member states forming the ESA we see today.

Throughout the 1970s and 1980s space science continued, with Europe, the US and the USSR sending various landers and probes out into the cosmos, famously culminating in the Voyager probes of 1977, which provided the first views of the distant, mysterious ice giants. In 1985 Japan became the third country to launch a deep-space probe with its Sakigake craft, developed by the Institute of Space and Astronautical Science for the National Space Development Agency (NASDA), both of which are now part of the modern-day Japan Aerospace Exploration Agency (JAXA). This experimental craft later joined international efforts to investigate Halley's Comet on its 1986 sojourn as part of the five-mission-strong Halley Armada. The collaboration involved a second Japanese craft, Suisei; two French-Soviet craft, Vega 1 and 2, which dropped landers on Venus before going on towards Halley, and the ESA's Giotto. Giotto would have been much less successful without measurements supplied by the other probes, highlighting the importance of teamwork.

There had been discussion before, between NASA and the USSR's Interkosmos programme, about the future possibility of combining America's Space Shuttle program with a Soviet Salyut space station - each nation playing on the strength of the other. This never materialised, the Soviets in the meantime working on the successor to Salyut and unfruitfully developing the Buran, its answer to NASA's shuttle. By the time the USSR was preparing to launch its Mir modular station in 1986, tragedy struck NASA when the Challenger shuttle exploded 73 seconds after launch. Sympathy poured in from across the world, each nation reminded how dangerous human exploration could be. NASA suspended spaceflight for two years in order to investigate safety concerns and restructure. The USSR went ahead with construction of Mir, the first module launched just a month after the disaster, though the last module would end up being transported by NASA's Atlantis nine years later.

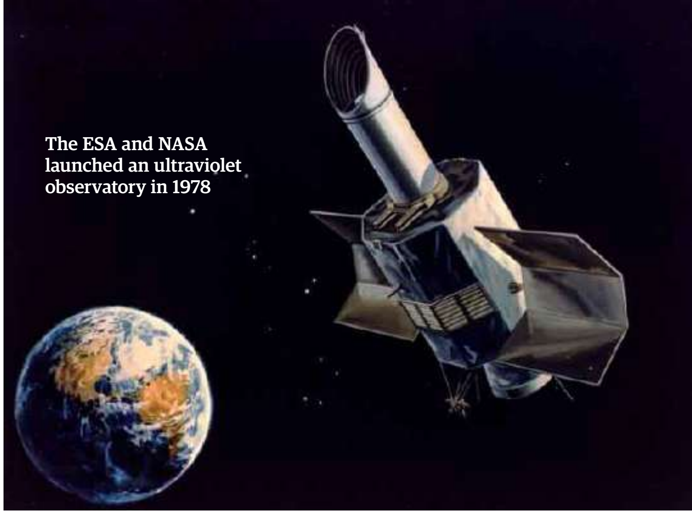
Japan became the third nation to launch a lunar probe, Hiten, which attempted to release a small orbiter into lunar orbit. Unfortunately the Hagoromo orbiter insertion failed, but two NASA Jet Propulsion Laboratory (JPL) scientists offered an unsolicited solution for Japan to salvage the mission, with calculations for Hiten itself to enter lunar orbit. Japan would implement this research, thankful to the US for its assistance in prolonging the mission.

In 1990 the Hubble Space Telescope launched, a joint project between NASA and the ESA. Hubble is still providing cutting-edge science 29 years later, and has proven a useful public relations tool with its stunning images of distant galaxies capturing the imaginations of people worldwide. The US also collaborated with Japan, the ESA and the UK on a collection of solar missions during the early 1990s.

The turn of the decade saw big political restructuring, when the USSR dramatically dissolved into 15 independent republics, officially ending the Cold War. With the collapse of the Soviet Union, its space programme was inherited by Russia and Ukraine, each forming its own agency. The Russian Aviation and Space Agency - now Roscosmos - would inherit most of this power, with Ukraine depending on its resources. The two have a unique relationship in that Ukraine has supplied Russia with military satellites and their launch vehicles. After the dissolution of the USSR plans for a joint

> "NASA suspended spaceflight for two years in order to investigate"

Vega was a joint project between the USSR and France



The ESA and NASA launched an ultraviolet observatory in 1978

NASA and Soviet astronauts train together for Apollo-Soyuz

enterprise between the US and Russia were revisited, the discussion of the 1970s not forgotten as the Space Shuttle and Mir docked for the first time in 1995, 20 years since Apollo-Soyuz. This collaboration was successful in proving the two old rivals could work together effectively, solidifying the idea that all space exploration was for international benefit. Russia's sharing of knowledge of long-duration spaceflight and space station construction would be paramount in the development and construction of the International Space Station (ISS).

Construction of the ISS began in 1998, a joint project between the Canadian Space Agency (CSA), ESA, JAXA, NASA and Roscosmos. Legal framework was established to define the rights of each country and outline what jurisdiction they had over their station modules. The pinnacle of space cooperation, the ISS has been continuously inhabited since November 2000; 236 people from 18 different nations have visited. It looks to be funded until at least 2025, though after that plans are unclear, with the US looking at commercial options and Roscosmos contemplating its use as a base for a new Russian station. Multinational astronauts on the ISS not only perform microgravity experiments to further space exploration, but they also tend to participate in education and culture outreach programmes, which get people across the world interested in space science and exploration.

On entering the 21st century the ESA became a space superpower of its own, sending craft to Mars and Venus and launching the first comet orbiter and lander. Legal restrictions on information sharing by the US military lead it to rely less on NASA, instead focusing on its own development. The Indian Space Research Organisation (ISRO) has also become a major participant in space research, in part thanks to the training and education given to Indian scientists and engineers by the US and USSR at the end of the Space Race. The ISRO's Chandrayaan-1 mission made India the fourth country to land on the Moon and it confirmed the presence of water in the lunar soil. This discovery confirms that rocket fuel may be able to be produced on the Moon, making international plans for a lunar-orbiting station or lunar base all the more viable in the future.

The China National Space Administration (CNSA) is also making great progress - though somewhat more privately - achieving human spaceflight in 2003 and continuing development of its Long March launch vehicles. The flight of Yang Liwei on Shenzhou 5 was met with much praise around the world; for instance, the USA wished the Chinese continued success with its programme - a starkly different reaction to that of Yuri Gagarin's flight, proving that nations now see the benefit in supporting and inspiring each other rather than concentrating on space domination.

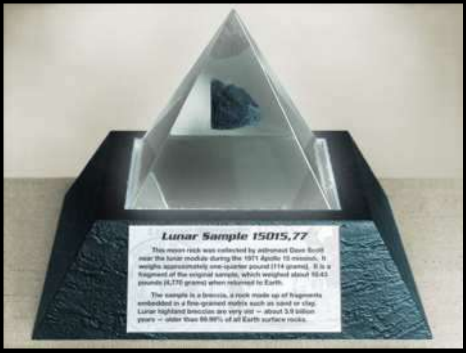
Space exploration is no longer science-fiction, with many nations looking to expand humanity's reach. Although the Outer Space Treaty has evolved and is still in effect, many countries look to develop their own space law and policy with the help of experts. Many nations are of the mind that international collaboration is essential in updating legislation to make sure that all nations are party to the same rules, no matter how technologically advanced. Space policy will become even more important in keeping the peace in space as commercial companies from different nations look to explore and harvest resources from other bodies. Hopefully all nations can reflect back on the Space Race and the cooperation that arose from it, keeping space travel for the good of all humankind - after all, from space you can't see borders.

ARTEFACT IMPACT

SPACE TECHNOLOGY CAN LIVE ON IN EXHIBITIONS AND INSPIRE THE FUTURE

Space travel is the no doubt greatest feat of human exploration. The Space Race was one of the most important events of the 20th century, making artefacts of this age extremely valuable. Unfortunately many craft and satellites have been lost to the atmosphere or over time before agencies realised their significance, but spacecraft, equipment and even old documentation from this era are on display in museums and private collections all over the world, with collectors paying handsome sums in auctions to own a piece of space history.

Space artefacts not only remind us of the great leaps made, allowing us to reflect on how far we've come since the 1950s, but also inspire future generations. Children touring space centres and going to exhibits in museums could be the astronauts of the future, inspired by the relics left behind by the first generation of space explorers. These exhibits and talks given by astronauts can also be useful in getting children interested in STEM subjects.



This sample of moon rock was collected by Dave Scott during the Apollo 15 mission in 1971

The module used by Czechoslovakian astronaut Vladimir Remek on return to Earth

Comparison of the Soviet Buran to the Space Shuttle

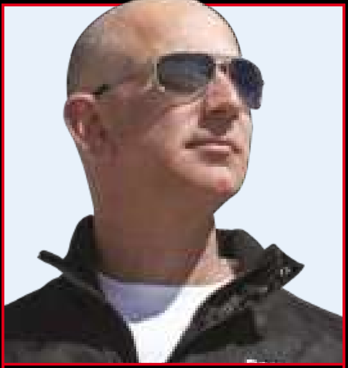
© NASA, NASA/W. Liller, NASA/Crew of STS-132, Creative Commons; Christo

The NEW SPACE RACE

Private companies and government agencies are racing ahead with ambitious plans to reach Mars, but who will get there first?

★ Written by Giles Sparrow ★

THE PLAYERS



BLUE ORIGIN

FOUNDED: 2000
FOUNDER: Jeff Bezos

The secretive Blue Origin aerospace company is developing pioneering reusable spacecraft that could play a key role in future Solar System exploration – but will it overtake its bigger rivals in the ongoing race to the Moon and the Red Planet?

BLUE ORIGIN

SPACEX

FOUNDED: 2002
FOUNDER: Elon Musk

The commercial spaceflight company SpaceX has already revolutionised the space industry with Dragon and the Falcon Heavy rocket, and Starship is a spacecraft like no other. But are the ambitious company's plans for a Mars landing in the next decade realistic?

NASA

FOUNDED: 1958
ADMINISRTRATOR: Jim Bridenstine

The US national space agency has a big budget on its side in the race for Mars, but delays to Orion and the SLS mean that it's still without a functional crewed spacecraft, and its necessarily cautious approach could take decades to put people on Mars.

VIRGIN GALACTIC

FOUNDED: 2004
FOUNDER: Richard Branson

Unlike its rivals, this company is developing reusable space planes to take tourists and payloads on a 90-minute suborbital flight. After reaching a significant milestone in December 2018, has the company accelerated the civilian space race?

Half a century ago, the dawn of the Space Age saw huge achievements, culminating in the Apollo Moon landings and humankind's first steps on the surface of another world. Now we're on the cusp of a bold new age where human explorers finally break free of Earth orbit, setting out on the much longer and more challenging journey to our next destination in space: the Red Planet. And just as those early leaps forward in space exploration were driven as much by fierce competition between political superpowers as they were by pure scientific curiosity, the new race to Mars is also inspired by a spirit of competition. This time, however, the players are not just rival national space agencies, but commercial enterprises and wealthy individuals with goals ranging from scientific curiosity and commercial exploitation, to nothing less than ensuring the future of the entire human race.

In the aftermath of the Apollo missions, scientists and engineers confidently predicted that the colonisation of Mars was the next obvious step in our exploration of the Solar System - it seemed inconceivable that almost 50 years later, astronauts would not even have returned to the Moon, let alone ventured beyond Earth orbit. More than one US president gave NASA a mandate to prepare for Mars, but in reality the thawing of Cold War tensions made expensive space budgets an obvious target for cutbacks. Meanwhile, rapid advances in electronics and computing allowed the development of robotic space probes that could explore the Solar System on their own terms, with far less cost and risk than sending human crews.

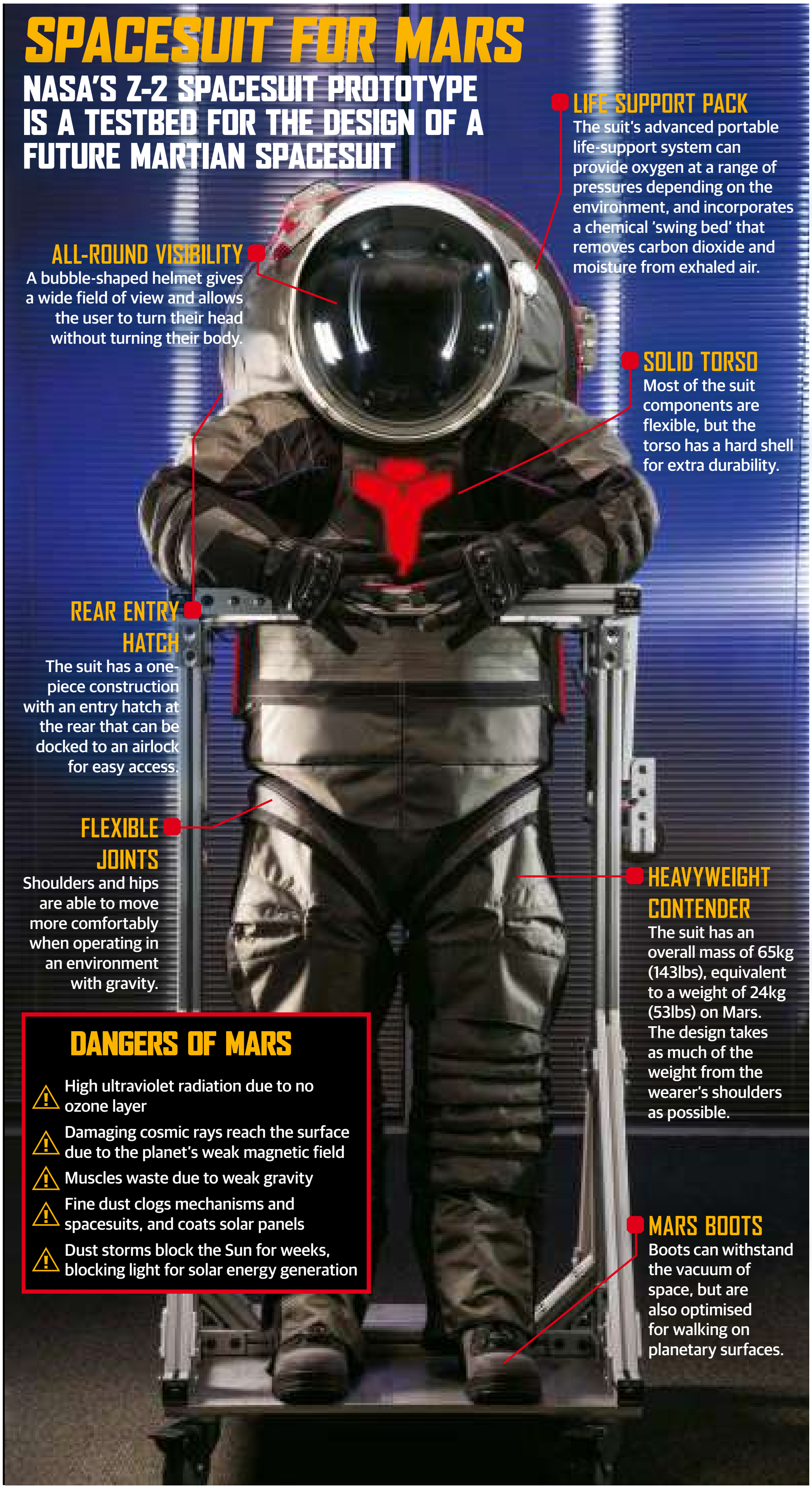
It took a traumatic event for things to change. The loss of the Space Shuttle Columbia during atmospheric re-entry in February 2003 led to the shelving of the entire shuttle programme as soon as work was complete on the construction of the International Space Station (ISS). In 2004, President George W Bush announced that NASA's mission would instead refocus on deep-space exploration beyond Earth orbit, with an ambitious new spacecraft and rocket system, the Constellation Programme, which would allow astronauts to establish a permanent settlement on the Moon and ultimately set out for Mars. And while NASA's new spacecraft were being designed and developed, the task of supplying the ISS would be turned over to new commercial spaceflight companies.

But rocket science is an infamously complex and expensive business, so perhaps it's little wonder that those ambitious plans didn't pan out quite as expected. In the face of delays and spiralling budgets, changes brought in by the Obama administration saw the twin launch vehicles of the Constellation Programme scrapped, and much of their technology incorporated into a new Space Launch System (SLS). NASA's crewed spacecraft, known as Orion, has also gone through some significant changes, and is currently scheduled to make a crewed flight by 2023.

What no one could have anticipated, however, is that the commercialisation of space travel, unleashed by NASA's change of focus, would prove so successful that it now threatens to beat the government agencies at their own game. There's a new space race underway and the players have set their sights not just on easier travel to Earth orbit, but also on targets

SPACESUIT FOR MARS

NASA'S Z-2 SPACESUIT PROTOTYPE IS A TESTBED FOR THE DESIGN OF A FUTURE MARTIAN SPACESUIT



ALL-ROUND VISIBILITY
A bubble-shaped helmet gives a wide field of view and allows the user to turn their head without turning their body.

LIFE SUPPORT PACK
The suit's advanced portable life-support system can provide oxygen at a range of pressures depending on the environment, and incorporates a chemical 'swing bed' that removes carbon dioxide and moisture from exhaled air.

SOLID TORSO
Most of the suit components are flexible, but the torso has a hard shell for extra durability.

REAR ENTRY HATCH
The suit has a one-piece construction with an entry hatch at the rear that can be docked to an airlock for easy access.

FLEXIBLE JOINTS
Shoulders and hips are able to move more comfortably when operating in an environment with gravity.

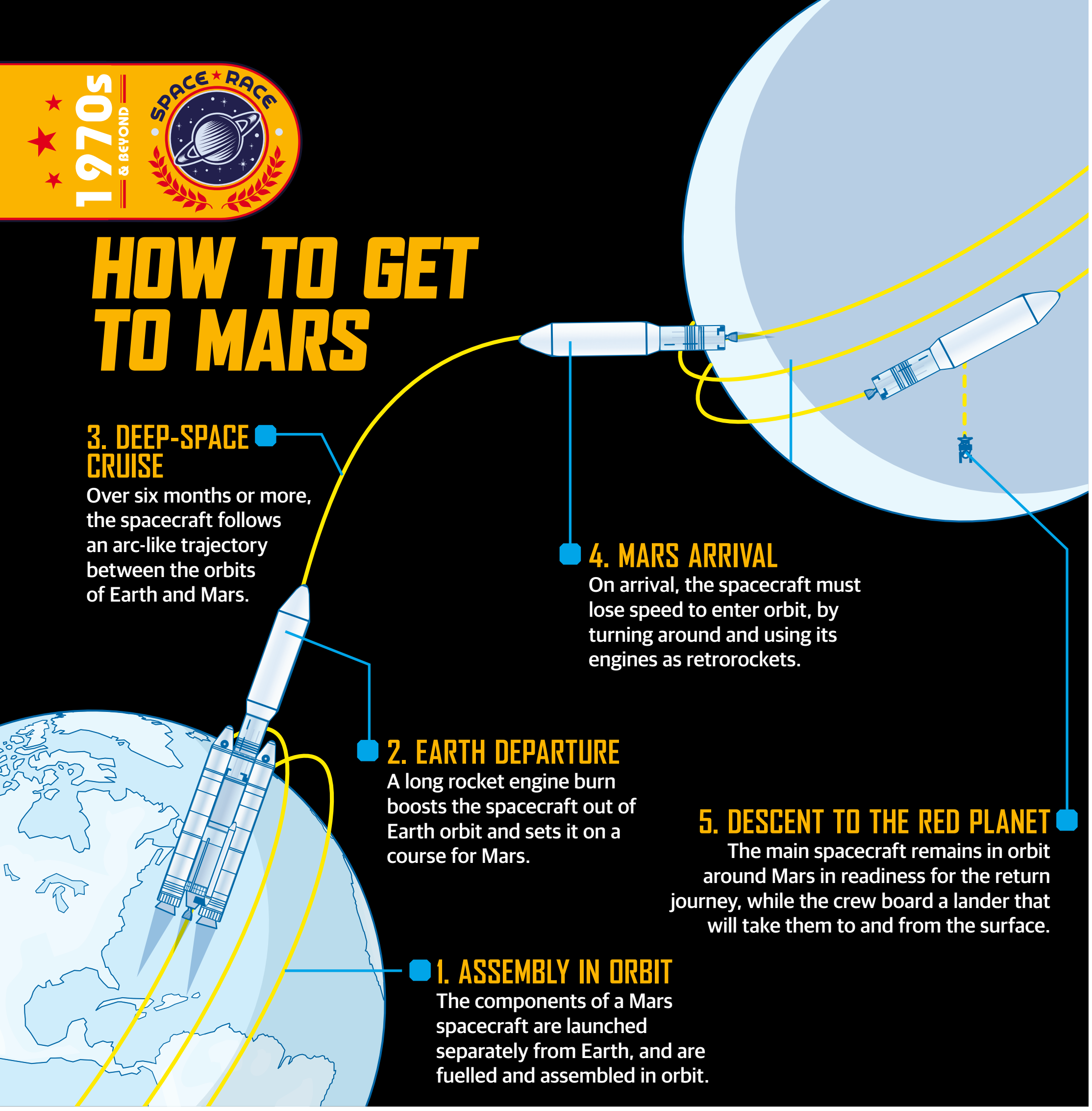
HEAVYWEIGHT CONTENDER
The suit has an overall mass of 65kg (143lbs), equivalent to a weight of 24kg (53lbs) on Mars. The design takes as much of the weight from the wearer's shoulders as possible.

MARS BOOTS
Boots can withstand the vacuum of space, but are also optimised for walking on planetary surfaces.

DANGERS OF MARS

- ⚠ High ultraviolet radiation due to no ozone layer
- ⚠ Damaging cosmic rays reach the surface due to the planet's weak magnetic field
- ⚠ Muscles waste due to weak gravity
- ⚠ Fine dust clogs mechanisms and spacesuits, and coats solar panels
- ⚠ Dust storms block the Sun for weeks, blocking light for solar energy generation

HOW TO GET TO MARS



1. ASSEMBLY IN ORBIT

The components of a Mars spacecraft are launched separately from Earth, and are fuelled and assembled in orbit.

2. EARTH DEPARTURE

A long rocket engine burn boosts the spacecraft out of Earth orbit and sets it on a course for Mars.

3. DEEP-SPACE CRUISE

Over six months or more, the spacecraft follows an arc-like trajectory between the orbits of Earth and Mars.

4. MARS ARRIVAL

On arrival, the spacecraft must lose speed to enter orbit, by turning around and using its engines as retrorockets.

5. DESCENT TO THE RED PLANET

The main spacecraft remains in orbit around Mars in readiness for the return journey, while the crew board a lander that will take them to and from the surface.

across the Solar System. Could it even be that private space companies will be the ones to make the first crewed landing on Mars?

In order to assess where the various players currently stand, we need to appreciate the scale of the challenge they face. A crewed mission to Mars is a vastly more difficult proposition than a return to the Moon. Most obviously, there's the distance involved: while the Apollo astronauts took just a couple of days to cross the 400,000 kilometres (248,550 miles) to our satellite, Mars is 56 million kilometres (34.8 million miles) away, even at closest approach – a journey of several months at Apollo-like speeds. What's more, the distance between Earth and Mars is constantly changing as each planet follows its own orbit around the Sun. Astronauts reaching Mars could not simply return to Earth after a few weeks on the surface – instead, they will be stuck there for around two years, which is the time it takes for the two planets to return to a close alignment.

All this time spent beyond Earth's gravity, protective atmosphere and magnetic field would pose considerable health hazards, and with short-term supply runs from home impractical, the crew will need to take everything they need with them, or manufacture it on Mars. As a result, it's likely that supplies (perhaps even a fully equipped Martian base) would need to be in place on the surface of the Red Planet before the astronauts even left Earth orbit.

And then there's the question of getting home again. A Mars mission might take the same approach as the Apollo program, with the main spacecraft waiting in orbit while the crew used a smaller vehicle to travel to and from the surface. But with such a long journey in both directions, the mission would either need to take a huge amount of unused fuel all the way to Mars, or refuel in orbit – and once again, the risks involved might mean placing a fully fuelled return vehicle in orbit before attempting a landing.

Fortunately, Mars is not the Moon – the environment may be hostile but as space probes have revealed its secrets, it has become clear that there is abundant ice in the Martian soil, which could be put to a variety of uses. A future settlement might be able to make not just water, but also oxygen and even rocket fuel for the return journey, in situ at Mars. The idea of manufacturing rocket fuel (specifically methane) at Mars, using an automated chemical plant sent from Earth, was first put forward in 1990 by engineers Robert Zubrin and David Baker as part of a cost-effective mission profile called Mars Direct, and as we'll see, it's already shaping the next generation of space technology even while a mission to Mars itself remains a distant dream.

NASA's own plans for an actual Mars mission remain tantalisingly (and perhaps wisely) undefined – for the moment, the agency is focusing on getting its new Orion spacecraft and SLS launch vehicle into flight. Once Orion is up and running in the next decade, the agency foresees the next step as a series of 'Proving Ground' missions in the space between Earth and the Moon. These would give the opportunity to attempt complex operations and test new technologies necessary for a Mars trip, while remaining within reach of Earth. Beyond that, perhaps in the 2030s, astronauts would begin 'Earth-Independent' missions – perhaps an asteroid

> *"It seemed inconceivable that almost 50 years later, astronauts would not have returned to the Moon, let alone ventured beyond Earth orbit"*

Inside the huge fuel tank of NASA's Space Launch System, welders complete the final plug fusion welds

> “When we have millions of people living and working in space, we want them to be able to go to lots of destinations. Mars would be one of them. The Moon would be another”
>
> Rob Meyerson, president of Blue Origin

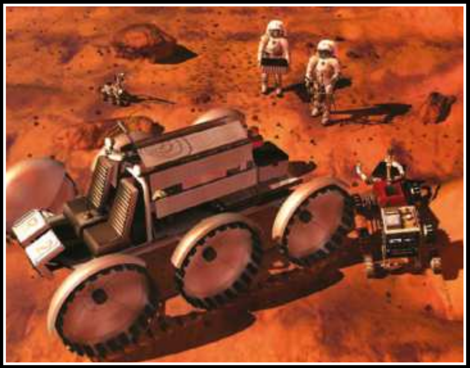
rendezvous and exploration, a trip to Martian orbit, or even the exploration of one of the planet’s tiny moons. Each of these would be considerably less risky than a full-blown landing, but still allow astronauts to test the limits of space endurance. At that rate, however, a full-blown landing might not happen before the middle of this century, and some people don’t want to wait that long.

Until recently, private space companies have kept their plans for reaching Mars under wraps, but in the past few months we've started to get a better idea of what some of them have planned. Leading the field is SpaceX, the company founded by Elon Musk, an entrepreneur who made his fortune with PayPal and who is now equally well known for the pioneering Tesla electric cars.

In 2008, the SpaceX Falcon 1 became the first privately funded, liquid-fuelled rocket to reach orbit, and SpaceX has since carved out a substantial business in the highly competitive satellite launch industry. As well as delivering cargos to the ISS using the larger Falcon 9 rocket and an uncrewed spacecraft called Dragon, the company has developed a human-rated version of the Dragon called Crew Dragon, which became the first American spacecraft to autonomous dock with the ISS in March 2019, as well as perfecting the complex technology to return rocket stages to Earth with a vertical touchdown, for later reuse.

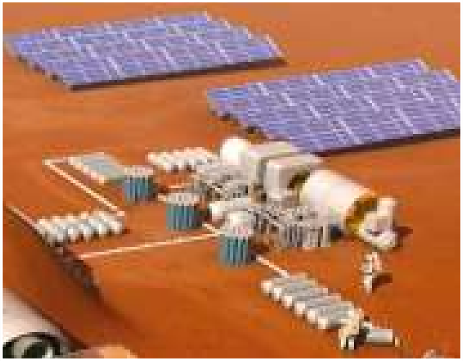
However, the full scope of SpaceX’s ambition was only revealed in September 2016 when Musk addressed the 67th meeting of the International Astronautical Congress and unveiled its so-called Interplanetary Transport System (ITS). Since then, the vehicle's design - and moniker - has been changed various times, and since November 2018 has been known as 'Starship'. This mammoth project involves a fully-reusable two-stage launch vehicle - a lower-stage booster that would return to Earth after each flight and an upper stage with a large integrated spacecraft that would make interplanetary voyages, after taking on fuel from a tanker launched separately into Earth orbit. Its Raptor rocket engines are designed to burn a mixture of liquid oxygen and

SUPPLIES



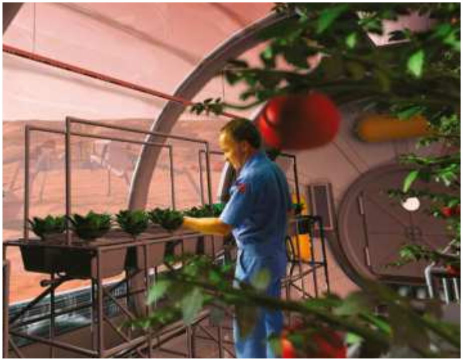
TRANSPORT

In order to explore the landing site, astronauts will need transport. This could range from small, agile buggies to a pressurised laboratory capable of spending weeks away from base.



AIR

Using electricity from solar panels, water molecules can be split apart in a process called electrolysis, releasing oxygen for life support systems and hydrogen that could be recycled in a fuel plant.

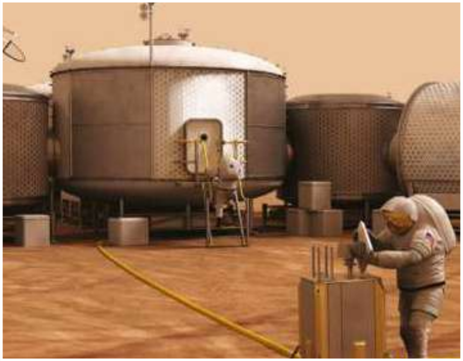


FOOD

With food supplies from Earth limited, astronauts will grow as much of their own food as possible – at first in sealed hydroponic greenhouses, but perhaps later in the Martian soil itself.

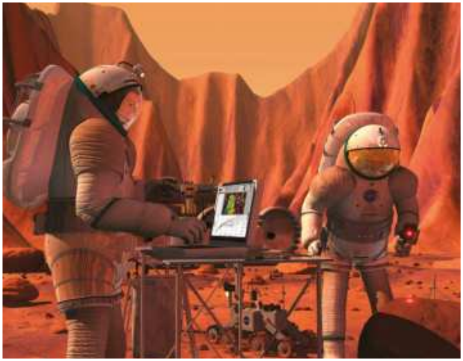
FUEL

Using the Sabatier process, a fuel plant could combine a hydrogen ‘feedstock’ with carbon dioxide from the atmosphere to form methane and oxygen. Stored in liquefied form, these could provide rocket fuel for the journey home.



SHELTER

Pressurised living quarters can maintain an Earth-like temperature and atmosphere, but burying them underground (in a cave or using a digger to cover the base in soil) would reduce temperature extremes and offer protection from radiation.



WATER

As well as its icy polar caps, we now know that the Martian soil is rich in frozen water ice, just below the surface. Once melted using solar energy, water could have a variety of uses – but any used for drinking would need to be carefully filtered first.

methane (fuels that can be manufactured easily at Mars), and the finished vehicle will be taller than the Saturn V Moon rockets and capable of launching more than twice the payload to Earth orbit. "What I really want to try to achieve here is to make Mars seem possible – like it's something we can achieve in our lifetimes," says Musk. And his interest, he says, is not just driven by curiosity about the Red Planet, but by concern for the future of humanity.

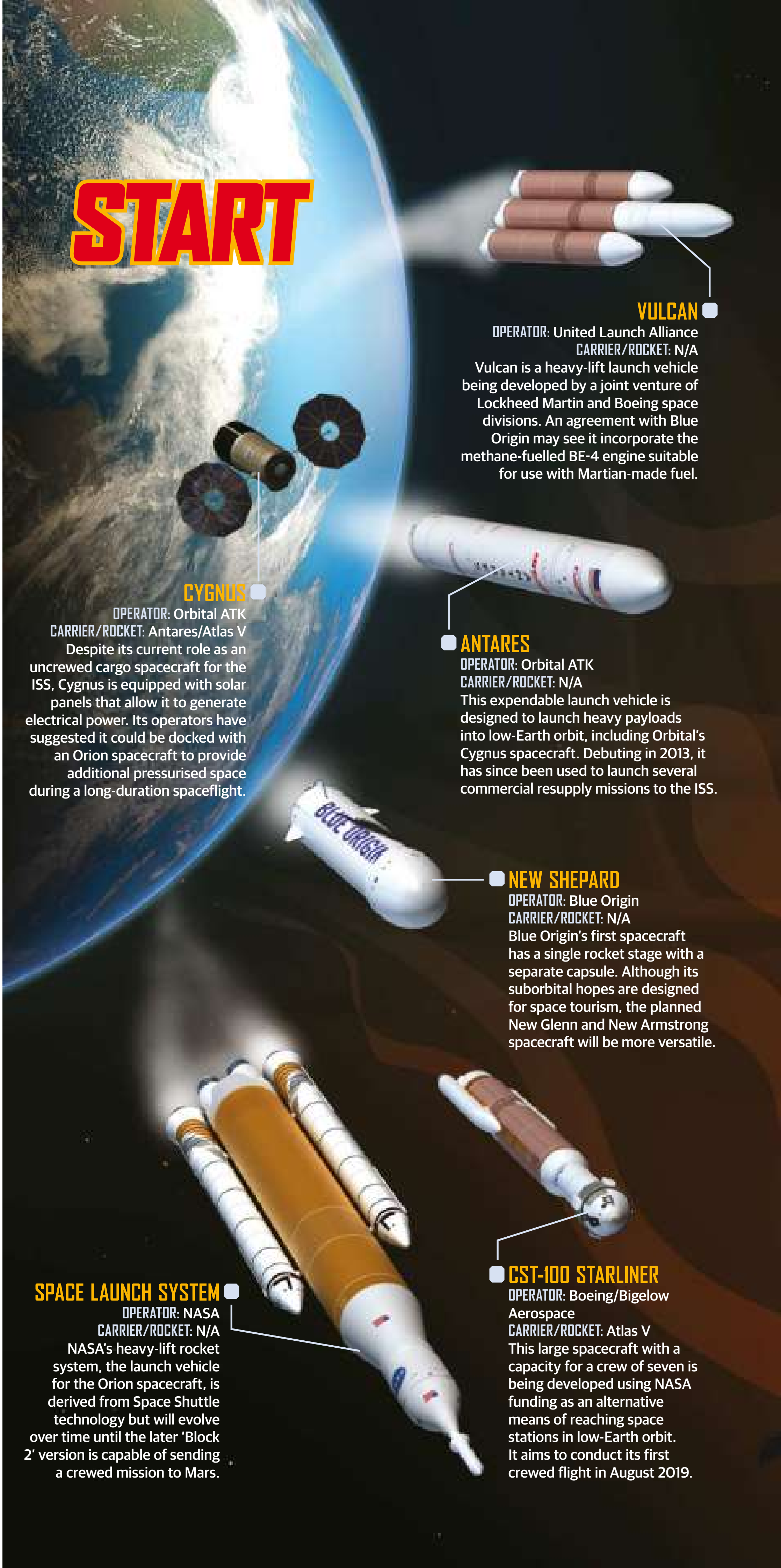
"I really think there are two fundamental paths: one is that we stay on Earth forever and then there will be an inevitable extinction event," he says. "The alternative is to become a spacefaring civilisation and a multi-planetary species." SpaceX has an admirable track record of fast rocket development, but even optimists would have to wonder if it's being too optimistic with its plans for a first crewed flight to Mars in 2024.

Taking a more measured approach is Blue Origin, another space venture founded by an internet entrepreneur (in this case, Amazon's Jeff Bezos). While SpaceX has aimed at the commercial launch market and NASA contracts, Blue Origin has remained rather more secretive, developing its own reusable technology and a reusable suborbital spacecraft called the New Shepard (after Alan Shepard, the first American in space). It's likely that New Shepard will carry its first crew later this year and the company is already moving on to more ambitious plans for an orbital spacecraft called the New Glenn, scheduled to make its first flight in 2012, and a seldom-mentioned advanced vehicle called the New Armstrong.

Questioned about plans for the Armstrong back in 2016, company president Rob Meyerson dropped some intriguing hints: "When we have millions of people living and working in space, we want them to be able to go to lots of destinations. Mars would be one of them. The Moon would be another. New Armstrong is really designed for that long-term vision." Blue Origin's vision and record so far suggest that they're thinking about the long term, developing spacecraft that may be used decades from now, rather than in a few years time. Another hint of an interest in Mars comes from the company's development of liquid oxygen/liquid methane rocket engines that could potentially be refuelled using Martian resources.

Just as government agencies are racing towards the Red Planet, billionaire technology pioneers are doing so too and they have a growing track record in the growing space industry. So will SpaceX astonish the world by putting people on Mars in the next decade, or will we have to wait a little while longer to see NASA reach the Red Planet? Technical hitches and a long enough delay might even allow Blue Origin or the fast-growing Chinese space programme to catch up. At the moment, it's perhaps too soon to tell, and the long history of planned Mars missions shows that few things ever work out quite as planned.

One thing is for sure, though – the new Space Race is driving space technology forward at a rate not seen since the 1960s, and whether we're wannabe Martians or not, we may all reap the benefits of this development.



VULCAN

OPERATOR: United Launch Alliance

CARRIER/ROCKET: N/A

Vulcan is a heavy-lift launch vehicle being developed by a joint venture of Lockheed Martin and Boeing space divisions. An agreement with Blue Origin may see it incorporate the methane-fuelled BE-4 engine suitable for use with Martian-made fuel.

CYGNUS

OPERATOR: Orbital ATK

CARRIER/ROCKET: Antares/Atlas V

Despite its current role as an uncrewed cargo spacecraft for the ISS, Cygnus is equipped with solar panels that allow it to generate electrical power. Its operators have suggested it could be docked with an Orion spacecraft to provide additional pressurised space during a long-duration spaceflight.

ANTARES

OPERATOR: Orbital ATK

CARRIER/ROCKET: N/A

This expendable launch vehicle is designed to launch heavy payloads into low-Earth orbit, including Orbital's Cygnus spacecraft. Debuting in 2013, it has since been used to launch several commercial resupply missions to the ISS.

NEW SHEPARD

OPERATOR: Blue Origin

CARRIER/ROCKET: N/A

Blue Origin's first spacecraft has a single rocket stage with a separate capsule. Although its suborbital hopes are designed for space tourism, the planned New Glenn and New Armstrong spacecraft will be more versatile.

SPACE LAUNCH SYSTEM

OPERATOR: NASA

CARRIER/ROCKET: N/A

NASA's heavy-lift rocket system, the launch vehicle for the Orion spacecraft, is derived from Space Shuttle technology but will evolve over time until the later 'Block 2' version is capable of sending a crewed mission to Mars.

CST-100 STARLINER

OPERATOR: Boeing/Bigelow Aerospace

CARRIER/ROCKET: Atlas V

This large spacecraft with a capacity for a crew of seven is being developed using NASA funding as an alternative means of reaching space stations in low-Earth orbit. It aims to conduct its first crewed flight in August 2019.

CHALLENGES ON THE WAY

HAZARDS OF LOW GRAVITY

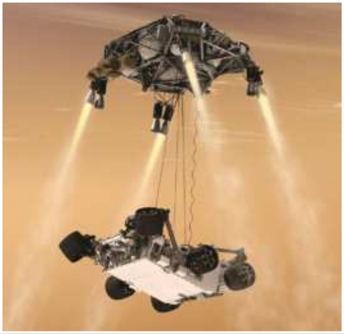
Long-duration spaceflight takes a toll on the human body, as muscles lose their strength and bone becomes less dense. Exercise during the journey would be a must to stay healthy.

NO TURNING BACK

Once a craft has left Earth orbit, the astronauts are on their own if anything goes wrong. Even if the mission aborted with a Mars slingshot, it would be unassisted for nearly a year.

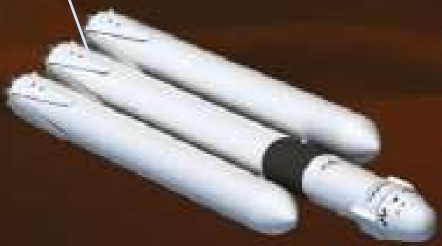
SPACE RADIATION

Outside of Earth's magnetosphere, high-energy radiation can cause cell damage that accumulates over time. A craft may need heavy shielding to protect it, increasing the cost.



ENTRY TO THE ATMOSPHERE

Weakened by months in space, the crew will need protection from the pummelling of atmospheric entry. Putting a heavy craft onto the surface requires complex descent techniques.



FALCON HEAVY

OPERATOR: SpaceX
CARRIER/ROCKET: N/A
Scheduled for its first launch this year, the Falcon Heavy adds two strap-on boosters to the standard Falcon-9 first-stage rocket, allowing it to lift heavier payloads to Earth orbit and send smaller ones, such as SpaceX's planned Red Dragon mission, towards Mars and other interplanetary targets.

STARSHIP

OPERATOR: SpaceX
CARRIER/ROCKET: Super Heavy booster
The ambitious Starship system includes a powerful booster stage using successful SpaceX rockets and a unique upper stage – a huge interplanetary spacecraft some 55m (180ft) long, capable of carrying 100 tonnes of cargo to the Moon or Mars.

CREW DRAGON

OPERATOR: SpaceX
CARRIER/ROCKET: Falcon series
SpaceX sucessfully completed its demostration flight of the Crew Dragon capsule in March 2019, marking a significant step in the return of manned spaceflights from the US closer to reality.

ORION CREW MODULE

OPERATOR: NASA
CARRIER/ROCKET: Space Launch System
The Orion Multi-Purpose Crew Vehicle (MPVC) is designed to carry four astronauts to destinations in interplanetary space. It will form the core of any NASA mission to Mars.

END

MARS DIRECT

Proposed by Robert Zubrin and David Baker in 1990, this sees an uncrewed Earth Return Vehicle launch to Mars before a crewed mission. After landing, it deploys a chemical plant for refuelling and generating other consumables. Some 26 months later a Mars Habitat Unit is launched. After six months in space, the crew of four explore the surface for 18 months.

STARSHIP

Details of SpaceX's crewed mission would involve Starship deploying a small crew and cargo including a propellant plant, vehicles and a basic habitat. The first crewed landing is targeted for 2024 – two years after the first cargo mission – and ultimately the spacecraft aims to carry as many as 100 people on long-duration flights to Mars.

ORION

First launched in 2014, NASA's Orion spacecraft will first be used to build a new space station around the Moon called the Lunar Orbital Platform-Gateway. Here, spacecraft bound for Mars can refuel, resupply or complete maintenence without having to return to Earth. NASA aims to send the first humans to the Red Planet in the 2030s.

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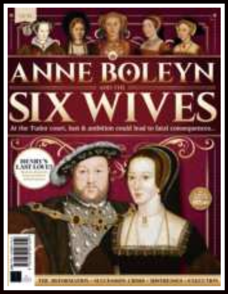

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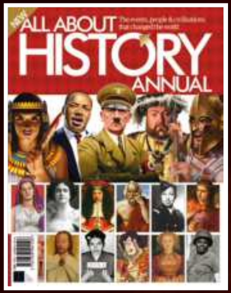

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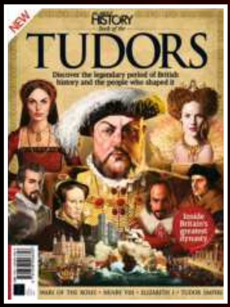

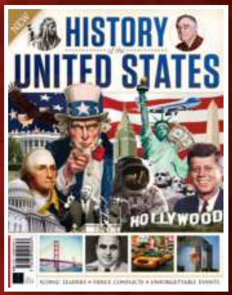

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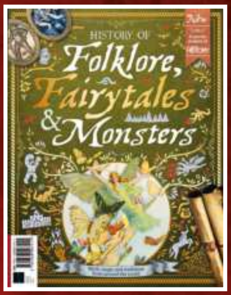
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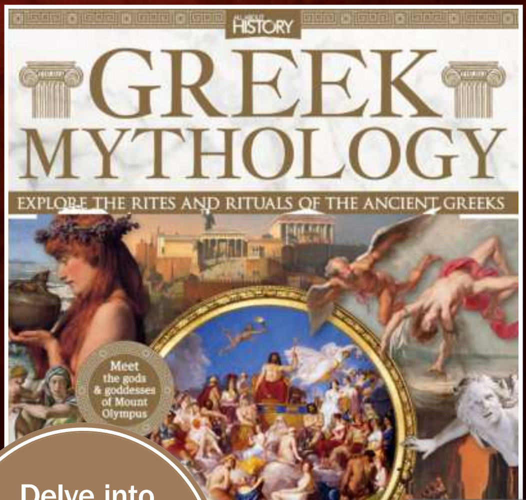
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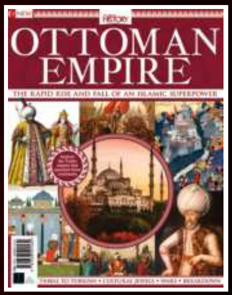
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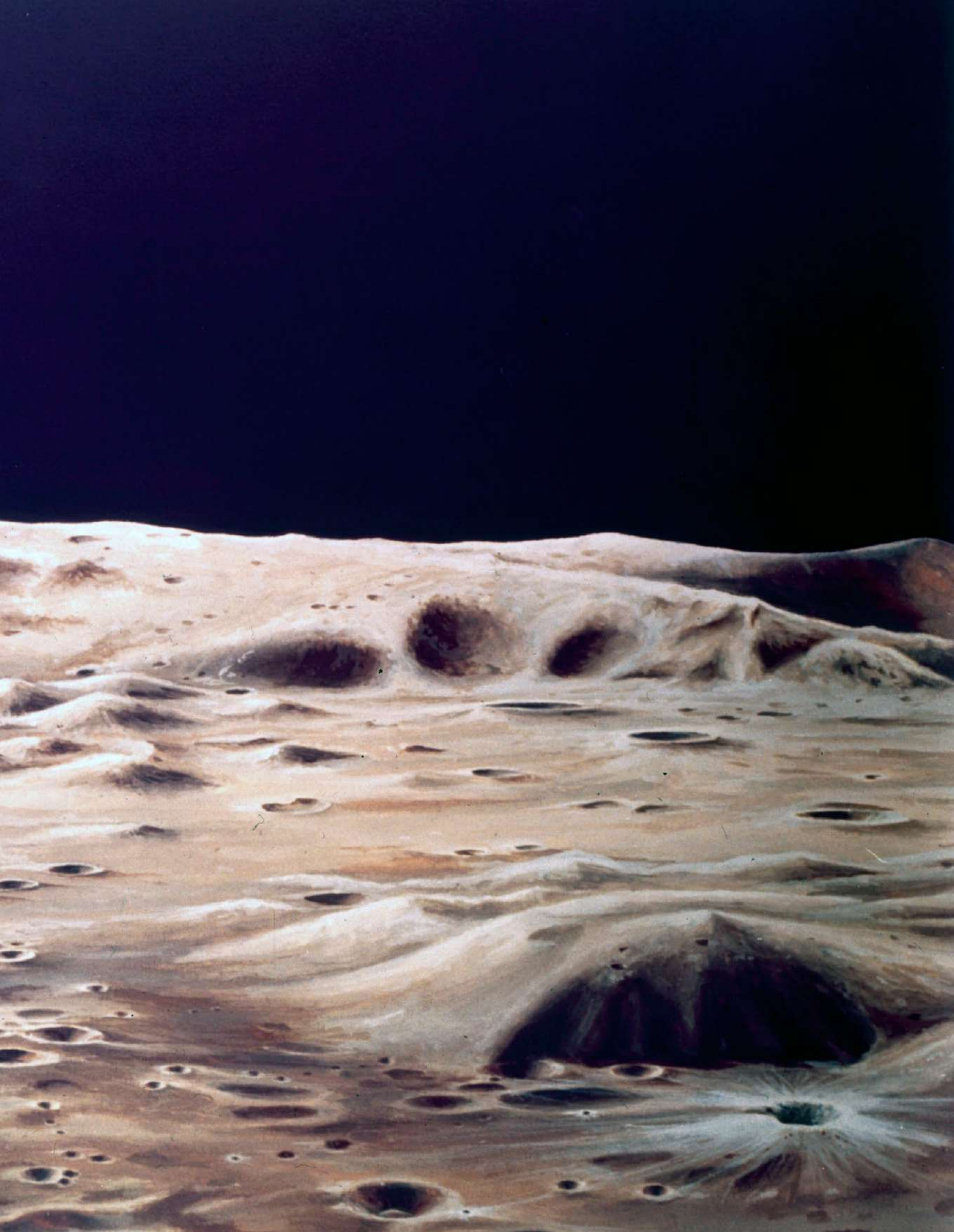

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